THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, M.D.

INTRODUCTION.

THE ANNAPOLIS ARMOR TEST.

THE competitive test of armor plates made at Annapolis on September 18th and 22d last, was in many respects specially noteworthy. Not that anything positively new was made manifest, nor as our ultra-enthusiastic journals will have it, that the armored fleet of Great Britain has been proved disastrously vulnerable. The test has added a great deal to the amount of data previously existing, whose comparison and coördination are necessary for direction in the true line of armor development.

To the artillerist there are several points connected with this test that make it of the greatest interest. 1st. Because a new material for armor has sustained its first public and crucial trial. This point is of the greatest interest in view of the result obtained. 2d. Because in the test, guns, projectiles, and plates were most admirably matched, so that the test furnishes a very maximum of reliable information. It can readily be understood that the choice of too high a caliber and projectile energy would have so completely pierced every plate at each shot that no margin would have been left for comparing effects, and, on the other hand, were the striking energy too light, so that all the plates had thoroughly resisted, no clear distinction could have been made. A wise measurement of the true power needed resulted in just taxing the plates sufficiently beyond their resisting powers to make a judgment simple and plain concerning them. 3d. Because not only was the test a public one in the amplest sense, but that the official report is clear and concise, and has been made public at the earliest moment. In this case it is not necessary to depend upon journalistic accounts, which, however well intentioned, almost invariably err in the omission of some really important detail, or in giving wrong data, or unintentionally giving a false coloring to results obtained. Nothing can be more distracting than to see a carefully written statement of a test where initial velocity is given and the distance of the plate from the gun is omitted, or where a gun caliber is given, and the weight and description of projectile are omitted; or where the minutest detail is given of the effects of a shot on the plate, whilst nothing is found regarding the effect of the plate on the projectile. The official report of this test is as remarkable for the completeness of its record as for its brevity. It contains exactly what is needed by the artillerist for study—nothing more and nothing less.

To those who have not made an intimate study of armor contests the comparative importance assigned to this test doubtless seems exaggerated. A thickness of plate of 10½ inches is not much in comparison with the 16- and 19-inch plates that have been the prominent subjects of contest abroad; and the 6-inch gun is a weak weapon compared with the 15- and 17-inch monsters that have been swung against plates in Europe.

In truth, though, this test cannot be belittled on the score of light plates and projectiles. The striking velocity of the 6-inch shells was higher than that of any test heretofore made, so that the power of the plates to resist punching was thoroughly tested. In addition to this, by bringing the 8-inch gun to bear against the already heavily punished plates, its shells having a striking velocity far below that of the 6-inch, whilst its total energy was enormously greater, the power of the plates to resist cracking, or disintegrating, or showing any of the defects attributed to racking was thoroughly tested. It is true that the plates were light as compared with the heavy belt plates of European battle ships, but the importance of the test cannot be belittled on this account without directly leading to an awkward conclusion that no artillerist would feel prepared to accept. Having given certain qualities of metal that, by proper treatment, will make a more or less perfect armor plate, the manufacturer encounters difficulties in developing these qualities, which increase very rapidly as the plate becomes thicker. These plates were furnished by the best manufacturers in the world, who not only have long been rivals, but whose business interests would be affected by the result. If, then, these plates were not thick enough to be of serious account, it is inevitable that compound armor must be condemned out of hand, for the compound plate failed where the others succeeded, and just so far as difficulties in perfect manufacture may be overcome, exactly to that degree does the inherent excellence of the material become manifest in the result.

It will not do to accept the results of this test as being true generally. Although the compound plate failed completely; it must be remembered that ever since the commencement of the rivalry between steel and compound plates, the comparative superiority has always been in doubt. It is but a few years since, in a competitive test in Russia, a steel plate fared as badly in comparison with a compound one as was the reverse in Annapolis. It is only by comparison of tests and of development that any true idea of the ultimate value of the materials of which the plates are composed can be determined.

Whilst it would be quite out of place here to attempt a detailed comparison of tests made against different steel and compound plates, it may be possible to point out a way by which anyone so inclined may, when he secures the data concerning any test, get a fairly correct idea of the relative resisting powers of different plates.

It is necessary, first, to take into consideration the scale of measurements, as it were; for it is readily seen how endless arguments will occur unless there be some common standard of reference. For example, in England compound plates beat English steel, where a projectile having 1975 feet striking velocity was used. At Annapolis, with the same thickness of plates, same caliber of gun, but 2075 feet striking velocity, French steel plates beat compound. Now, it would be interesting to know whether the steel at Annapolis was better than the steel in England, and if so, whether it was better than the compound plate in England, and whether the English Cammell plate was better than the American Cammell plate. Then again, how is one to compare the results of 6-inch projectiles on 10-inch plates with those of 11-inch projectiles on 15-inch plates? There is a method, not at all abstruse, which will give a fairly true basis of comparison. It is only necessary to prelude the description with the warning that a knowledge of this method and of the results obtained does not make one an expert judge of armor, and that it requires an expert to properly weigh all the circumstances of any test. By the use of this method one could not well prescribe what should be the conditions of a test to be made, but since tests are prepared and carried out by experts, due regard has been had to the proper composition of the elements, so that results translated or compared by this true method will be nearly correct.

Before wrought iron passed out of service as failing in resisting power, plate manufacture had been so perfected throughout Europe that not only was it remarkably constant in its resisting power, but this power was practically the same wherever the plate was made. That is, no manufacturer could claim any particular superiority in resisting power for his product. Projectiles had so far developed that not only steel but chilled iron ones would readily pierce these plates without being either broken or deformed. Thus it became possible to compute by rigid formulas the exact amount of energy required to send a projectile of a certain caliber through a plate of a given thickness.

As compound and steel plates came in to replace iron ones, two great difficulties were met with in attempting to compare results obtained. The development in manufacture was slower and much more difficult, so that very great variations were met with in the resisting power of similar plates. So great, that it was found impossible to formulate the results in any way that would be even remotely satisfactory. The best that could be done in the way of conveying an intelligent idea was to adopt wrought iron as a standard of reference, which its regularity permitted, and to speak of a steel or compound plate as being equivalent to a certain greater thickness of wrought iron. It must be remembered that a mere expression of a certain number of foot-tons of energy conveys no intelligible idea, even to the expert, for it requires different energies to force shells of different calibers through a plate of a given thickness. It was more definite to say, for instance, of a 10-inch compound plate that it was equivalent to 12½ inches of wrought iron; for, at least, by this means one could get at some idea regardless of caliber of projectile.

The other difficulty was that the power of the plates was sufficient to smash or distort the best projectiles that could be brought against them. That a plate should be capable of smashing a projectile is creditable to the plate within certain limits; but we evidently cannot determine the comparative resistance of two plates if both break their projectiles, for we have no standard of measurement. There is an immense difference between making a projectile test the strength of a plate and making a plate test the strength of a projectile.

Projectiles gradually improved in strength until in the Holtzer shell they seem to be developed to a point where the most powerful armor cannot break or deform them, as a rule. This acquisition brings us at once within a fair and safe measuring distance of our standard, and we may in a single expression convey to the mind a definite idea, where not only can we omit the caliber of projectile, but also the thickness of plate itself, and thus we arrive at a direct comparison of armor systems. The method of arriving at this expression is as follows:

Assume a steel plate of 9 inches thickness, against which a Holtzer shell is fired with a certain energy, and assume that this shell barely pierces the plate. Take one of the many well-known formulas for penetration of wrought-iron plates (the Gavre formula recommends itself by its simplicity and flexibility), and compute the energy necessary barely to send *that same* projectile through a wrought-iron plate of the same thickness. Suppose it to be found that this energy is 1000 foot-tons.

Now compute the actual energy with which the projectile struck the plate and assume that this energy is 1070 foot-tons. Then 1070 divided by 1000 equals 1.07, and we translate the expression by saying that the steel plate is a seven per cent plate. That is, that it requires seven per cent more energy to pierce it than would be required for a wrought-iron plate of the same thickness. The beauty of this expression is that, no matter what be the caliber of projectile brought against the plate, it is always a seven per cent, as compared with the same projectile against wrought iron, and no matter what may be the thickness of plate, the per cent always holds against a corresponding thickness of wrought iron. So then, by this expression we may grade plates in resisting power, whether they be steel, compound, or nickel-steel; and we may directly classify the nineteen-inch plate attacked by the fifteen-inch shell with the nine-inch plate attacked by the six-inch shell.

It is well to point out two features that interfere with the absolute truth of this expression: 1. The projectile must not be smashed or distorted by the plate, as the resulting per cent value will be much too high. If one looks at any authority of five years ago, it will be found that both steel and compound plates are said to be from twenty-five to thirty per cent higher in resistance than iron plates. The advent of perfected projectiles upset this estimate completely, and forced the manufacturers to renewed and strenuous exertions. 2. The plate must not split or smash under the blow. This frequently happens and gives constant renewal to the old argument of racking versus punching, but to those who have carefully followed and studied the course of armor development it seems certain that as any system of armor improves, racking effects, which at first are invariably predominant, are gradually overcome until in the end they disappear entirely, whilst the resistance to punching is maintained or increased. The Annapolis test brings these features out very prominently, for the nickel steel showed both punching and racking resistance; the steel plate showed punching resistance, but was racked; the compound plate failed in both features.

This method of classifying armor is here put forward for the first time. The method is by no means novel, but no utilization of the resulting expression seems to have heretofore been made, and it appears to be particularly well adapted to common use.

A few citations will bring out the character of the expression, and doubtless give a clearer idea of the strength of the plate exhibited at Annapolis.

In 1888 a lot of 6-inch Holtzer shells were delivered to the English Government under the stipulation that when fired against a 9-inch compound plate they should not break or be notably deformed. Under test they readily pierced the plate, and it is found by computation that the test was what might be called a twelve per cent one; or, as the plate was pierced with considerable to spare, it could not be classed as high as twelve per cent.

In the early part of 1888 an important test of armor plates took place at Portsmouth, England, at which the plates and 6-inch projectiles were exactly assimilated to those of the Annapolis test, the striking velocity being 100 feet less. This, by the method of classification, was a seven per cent test, and was well resisted by a Cammell compound plate, and a Vickers steel one. The test at Annapolis was an eighteen per cent one, and the Cammell plate broke down under it. Here, by this single expression a deal of light is thrown upon the action of the Cammell plates in England and here.

Not long ago, at St. Petersburg, an 11-inch projectile was fired against a 15½-inch Cammell compound plate, the projectile barely getting its point through. The test was a five per cent one, and compares excellently with the one quoted as at Portsmouth, although plates and projectiles were widely different. Let it be remarked that neither of these two plates was noticeably racked, nor were the projectiles hurt. Both plates apparently would take the same classification, which would be more than seven per cent.

At Gavre a 19.7 inch Schneider plate was tested with a 15¼-inch projectile, both standing well up to the work. The test was a fourteen per cent one, and the projectile pierced with considerable to spare.

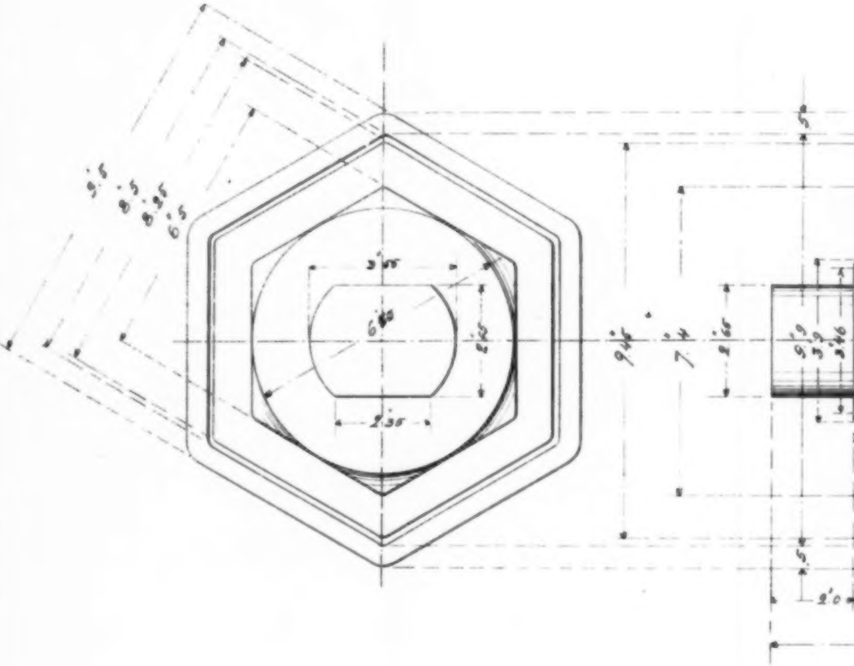
At Le Bouchet a 5½-inch Schneider plate received a thirteen per cent test, which exactly limited its classification, the shell barely going through.

The examination of a great number of tests made under proper conditions leads to the conclusion that this method of classification is very fairly correct. Under it, the steel and nickel-steel plates tested may be classed fairly as eighteen-per-cent plates, while the Cammell plate must fall below them, although taking the Portsmouth and Annapolis tests together, it is fair to place it well above seven per cent, and presumably quite close to twelve.

In closing, it may be well to add a few remarks concerning the English sentiment in favor of compound armor, since much of an uncomplimentary nature has been said of late. The Annapolis test, beyond all doubt, gave a decided victory to steel over compound plates; but it will not do to jump to the conclusion that compound plates are worthless. For nearly fifteen years the struggle has been going on without any decision as to supremacy. Compound armor has, at times, been far in the lead—so far, that even France, the home of steel plates, opened its doors very wide indeed to compound ones. Leave the ships of Great Britain entirely out of consideration, and there will remain far more ships built with compound than with steel armor. Nor should we be carried away by the idea that the British artillerists are averse to steel. From the very inception of armor, steel has been constantly tried, and with such excellent results and constancy, that it could scarcely be called revolutionary were England to throw compound armor overboard to-morrow.

The United States is especially fortunate in coming to the study of the best system to adopt, after projectiles had reached the stage where they could outmatch armor in withstanding punishment. Before that the contest between steel and compound armor was indifferent and unsatisfactory. Now all is different, and one system, perhaps both, must soon go to the wall. The United States has entered to aid in solving the grand problem; and, whilst we must bear in mind that "one swallow does not make a summer," we may properly boast that our first test was not only thoroughly excellent, but that one of the plates clearly showed a greater power of resistance than has ever been developed heretofore.

EDWARD W. VERY.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6.65
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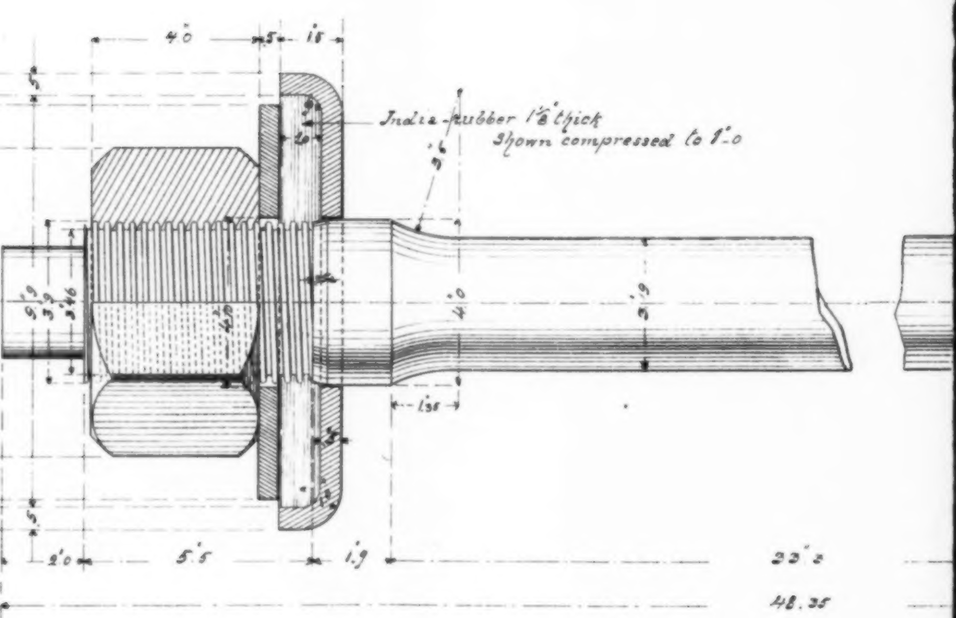
THE DEUTSCH LITH. & PTG. Co. PHOTO LITH. BAL'O.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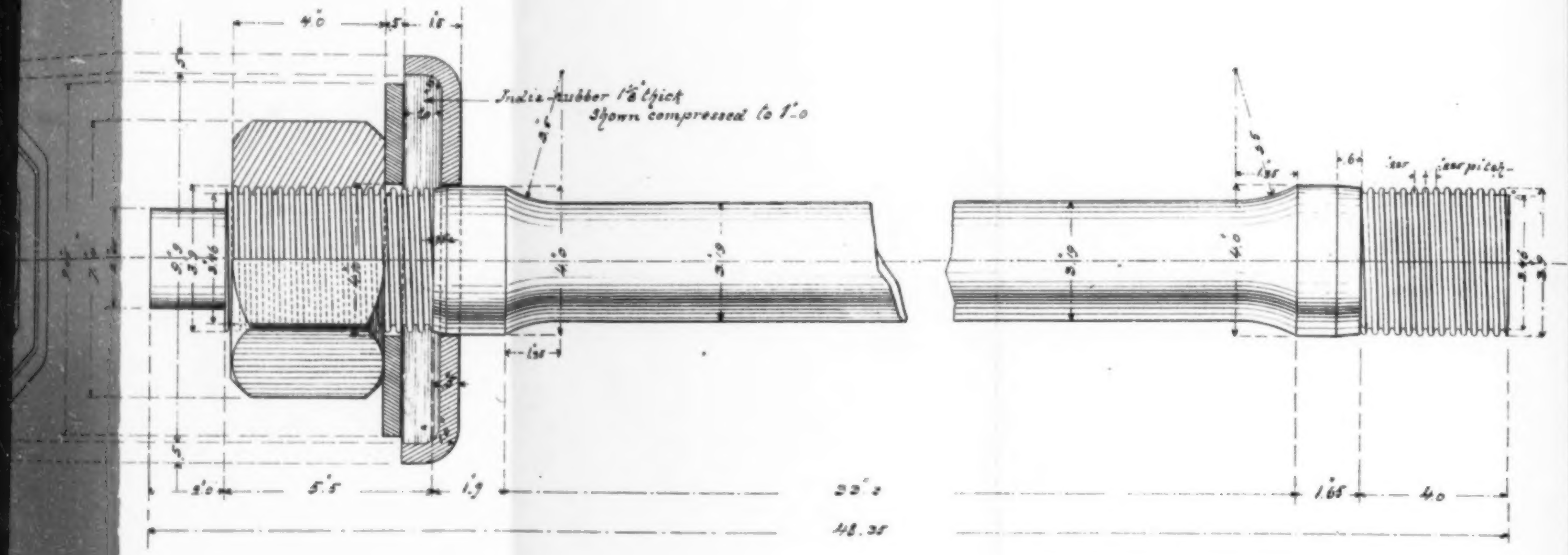
.5
1.5
India-rubber 1.5" thick
Shown compressed to 1".0
3.6
.5
1.0
9.9
3.9
3.46
4.0
4.0
3.9
1.35
.5
2.0
5.5
1.9
33.2
48.35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4.0
3.9
1.30
2.0
5.5
1.9
32.2
1.65
4.0
48.35

Armor Bolt
for
Cammell Compound Plate.

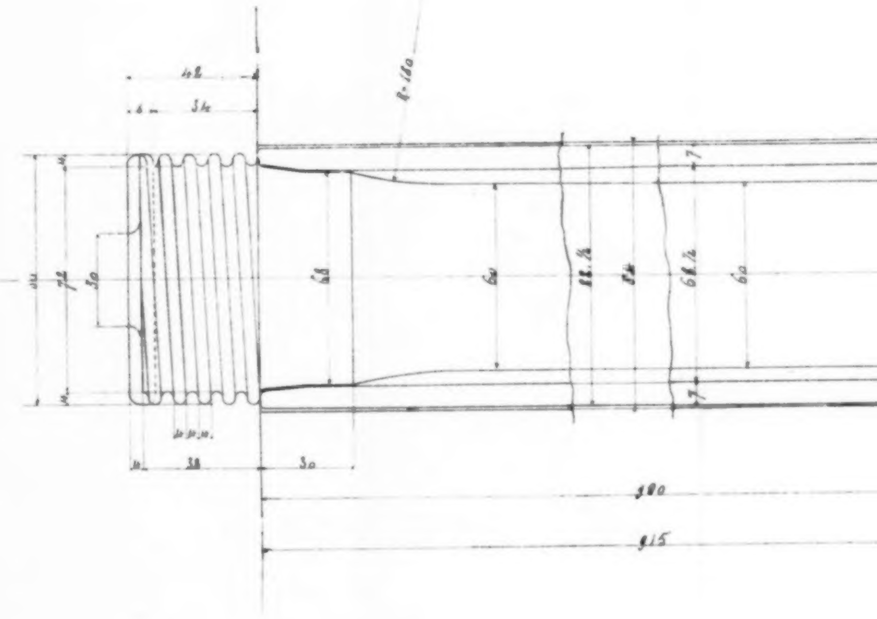
Bureau of Ordnance
Oct. 8-1890

1610.

C. Weller

PRO

Dessin N° 730/90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R=180
88
72
30
10
68
60
88.2
84
68.2
60
7
7
10 10 10
10
38
30
380
915

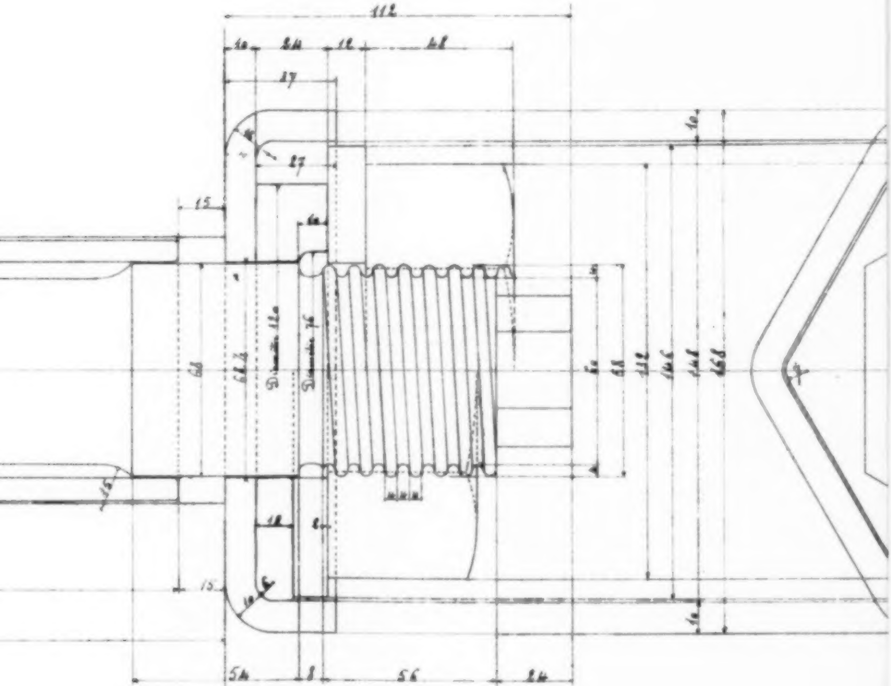
THE DEUTSCH LITH & PTG. Co. PHOTO-LITH. BALTO.

Gouvernement des Etats-Unis

Ministère de la Marine

Essais de compétition de plaques de blindage

Boulons de tenue de la plaque sur la cible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24
12
48
27
27
15
15
68
68.2
Diamètre 120
Diamètre 76
60
88
112
126
141
168
10
10
18
8
15
54
8
56
24

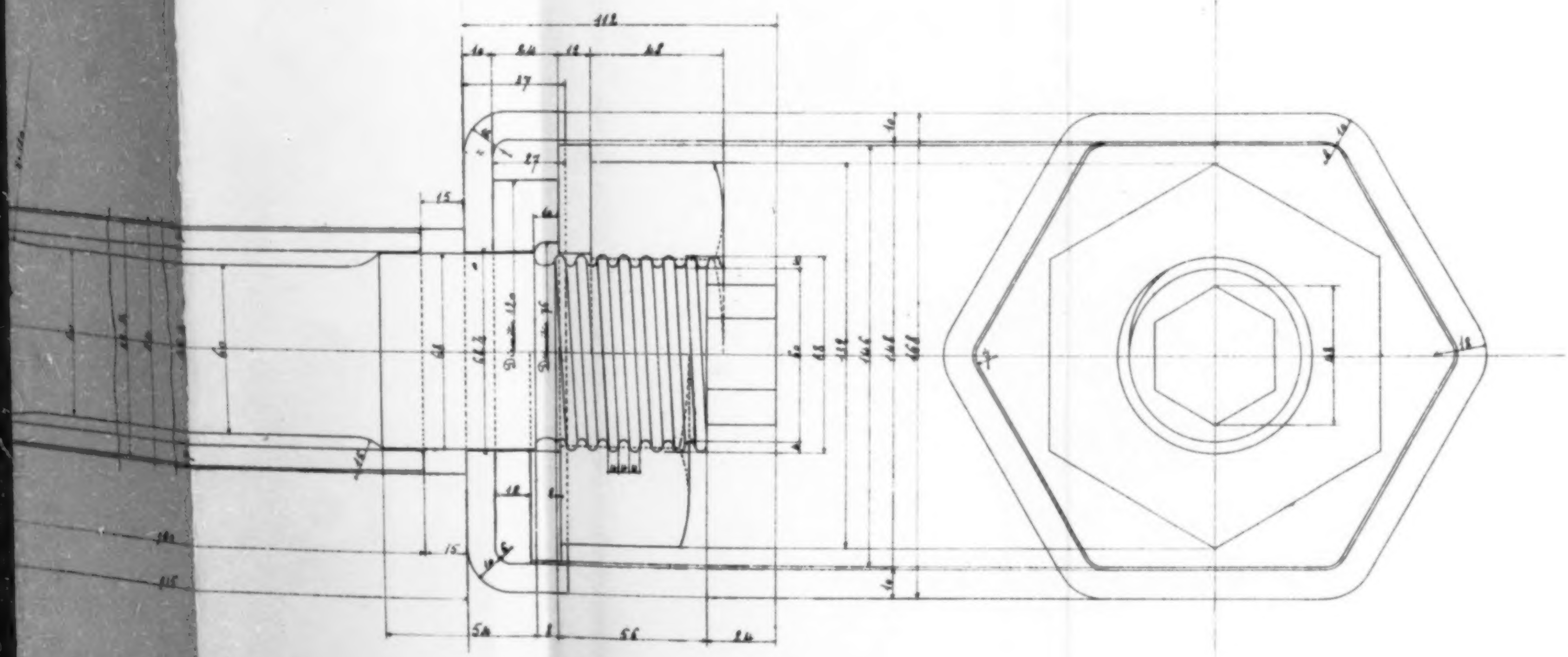
Dimensions de la plaque { Hauteur ———— 2^{m} 438
Largeur ———— 1 828
Epaisseur ———— 0^{m} 2679
Poids de la plaque ———— 9 330$^{k.g}$
Nombre de boulons fixant la plaque ———— 12
Section d'un boulon (D. 60$^{m}/_{m}$) ———— 28$^{cm^2}$ 27
Section totale des 12 boulons ———— 339$^{cm^2}$ 29
Section de boulons par 1000$^{k.g}$ de plaque ———— 36$^{cm^2}$ 36
Epaisseur de la muraille ———— 0^{m} 915

Gouvernement des Etats-Unis

Ministère de la Marine

Essais de compétition de plaques de blindage

Boulons de tenue de la plaque sur la cible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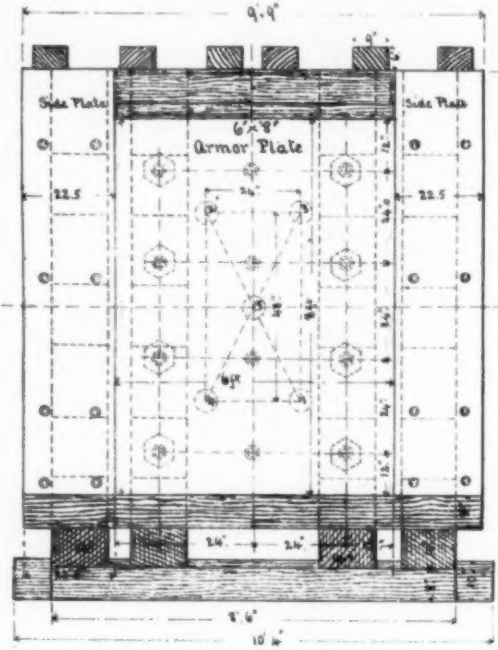
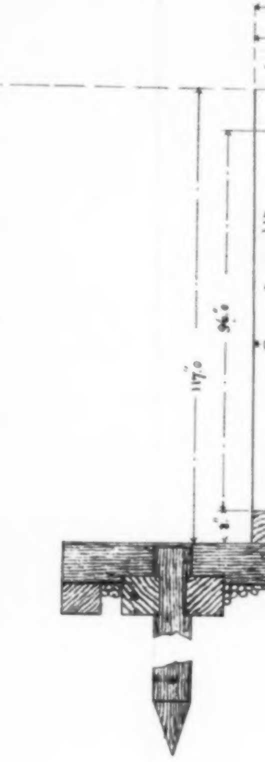
12
48
27
27
15
15
18
8
54
8
56
24
60
10
10
Diamètre 120
Diamètre 76

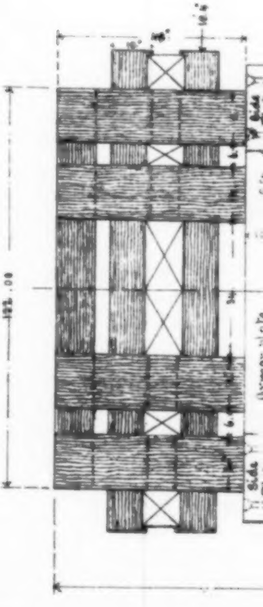
Dimensions de la plaque	Hauteur	2ᵐ 438
	Largeur	1 828
	Épaisseur	0ᵐ 2679
Poids de la plaque		9 330 k°
Nombre de boulons fixant la plaque		12
Section d'un boulon (D. 60 m/m)		28 cm² 27
Section totale des 12 boulons		339 cm² 29
Section de boulons par 1000 k° de plaque		36 cm² 36
Épaisseur de la muraille		0ᵐ 915

Creusot le 23 février 1890

To face page 629


9' 9"
9"
Side Plate
Side Plate
6'×8'
Armor Plate
22.5
22.5
24"
24"
24"
8' 6"
10' 10"





TARGET STRUCTURE,

FOR

TEST OF ARMOR-PLATES.

(TIMBER,-OAK)

(ARMOR-BOLTS CONVENTIONAL.)

SCALE $\frac{1}{20}$th

Bureau of Ordnance

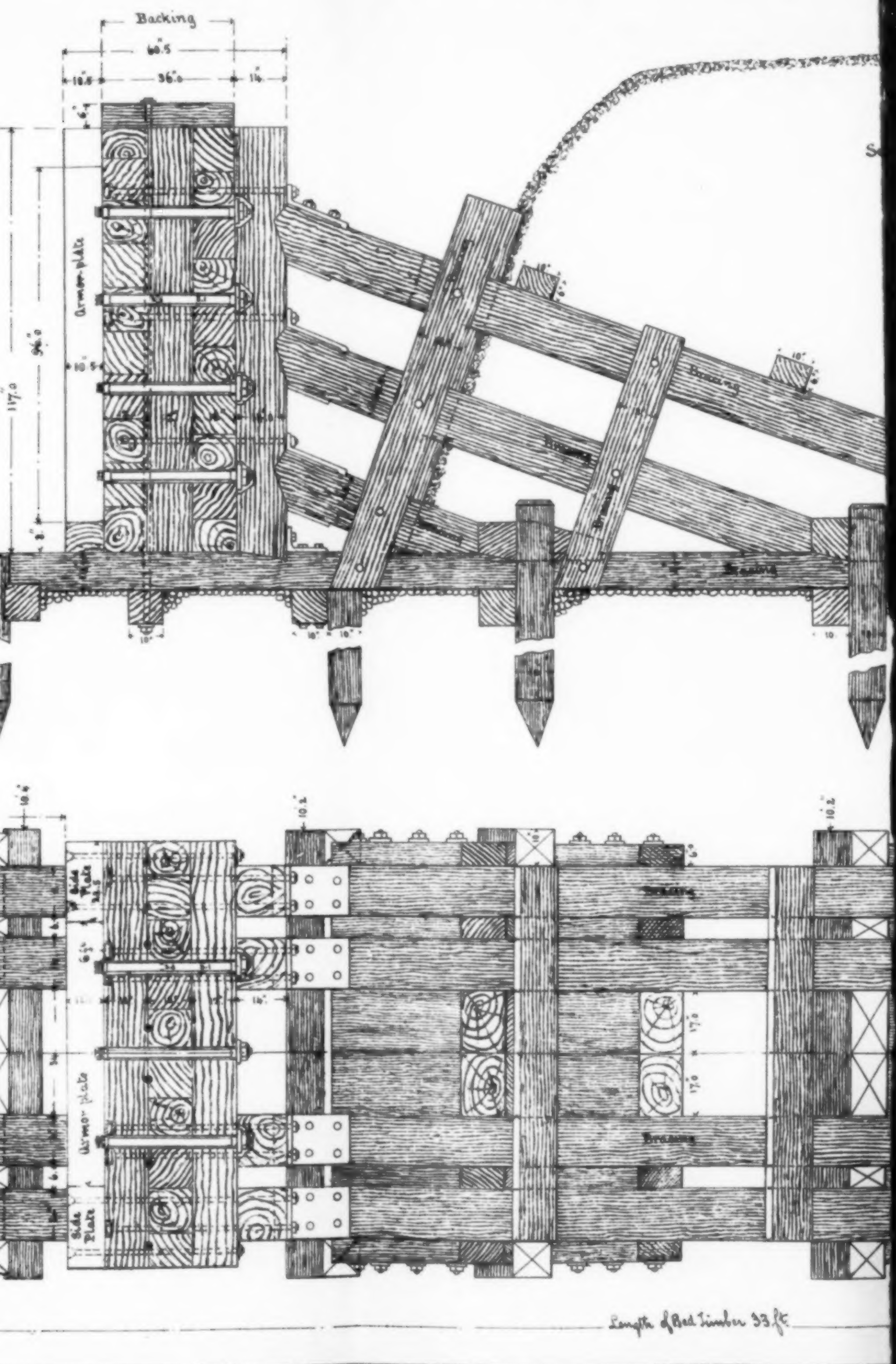
Decem: 2nd 1889.

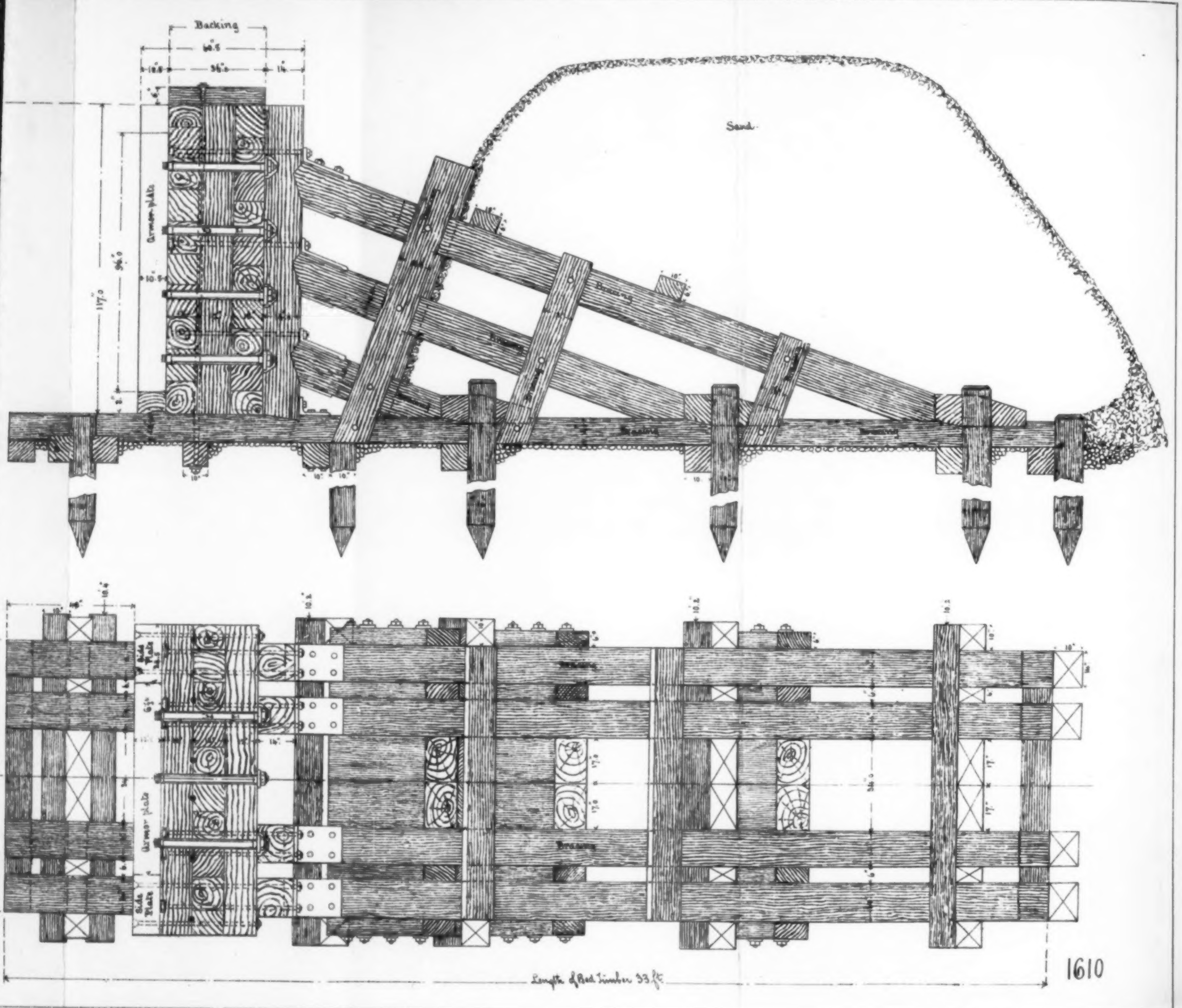
Approved

M Sicard

Chief of Bureau

THE DEUTSCH LITH. & PTG. CO. PHOTO LITH. BALTO.


Backing
60.5
10.5
36.0
14"
6"
Armor-plate
96.0
117.0
10.5
10.0
8"
Bracing
Bracing
Bracing
Bracing
Bracing
Bracing
10"
10"
10"
10"
10
10.2
10.2
Side Plate 32.5
6½"
14"
Armor plate
Side Plate
Backing
Bracing
17.0
17.0
Length of Bed Timber 33 ft.


Backing
60.5
18.5
36.0
14
Armor plate
117.0
36.0
10.5
Sand
Bracing
Bracing
Bracing
Bracing
10
Side Plate
Armor plate
Side Plate
Bracing
Bracing
17.0
17.0
36.0
Length of Bed Timber 33 ft.

1610

REPORT OF THE BOARD ON THE COMPETITIVE TRIAL OF ARMOR PLATES.

NAVAL ORDNANCE PROVING GROUND,
ANNAPOLIS, MD., OCTOBER 11, 1890.

IN obedience to the Department's order of July 11, 1890, the Board met at the Naval Ordnance Proving Ground, September 18, 1890, for the purpose of conducting a competitive test of three armor plates, one of steel and one of nickel steel manufactured by Schneider & Co., Le Creusot, and one compound plate manufactured by Cammell & Co., Sheffield.

The Board made a careful preliminary inspection of the plates and their bolts and backing. They were all erected in accordance with a drawing furnished by the Bureau of Ordnance to the Inspector of Ordnance-in-Charge at the Proving Ground. The steel plate and nickel steel plate were secured to the backing with twelve bolts 2.36 inches in diameter. The compound plate was secured to its backing by eight bolts 3.19 inches in diameter.

Plate.	No. of bolts.	Diameter of bolts.	Total bolt cross-section.	Weight of plate.	Bolt section per ton of plate.
			Sq. inches.	Lbs.	Sq. inches
Steel	12	2.36″	52.29	20776 (actual).	5.66
Nickel steel	12	2.36	52.59	20679 (actual).	5.69
Compound	8	3.19	64.32	20992 (calculated).	6.86

The plans of the backing, the arrangement, shapes, and method of securing the armor bolts are shown in the photographs appended.

Caliper measurements were taken by Lieutenant-Commander Dayton along the edges of the plates before they were secured. A table of these is appended.

CALIPER MEASUREMENTS OF ARMOR PLATES.

Commencing at lower right-hand corner, up right edge, across top, and down left side, at intervals of one foot.

Point of measurement		Schneider all steel.	Schneider nickel steel.	Compound.
		Inches.	Inches.	Inches.
Lower right corner		10.56	10.22	10.65
Right side	1	.61	.45	.63
	2	.61	.65	.76
	3	.58	.65	.81
	4	.53	.64	.70
	5	.52	.49	.76
	6	.51	.45	.80
	7	.53	.38	.70
Upper right corner . . .		.55	.24	.70
Top	1	.59	.38	.69
	2	.60	.41	.71
	3	.61	.41	.77
	4	.63	.41	.75
	5	.63	.38	.74
Upper left corner. . . .		.55	.27	.67
	1	.56	.34	.70
	2	.51	.38	.59
	3	.55	.42	.67
	4	.53	.43	.71
	5	.58	.43	.67
	6	.63	.41	.69
	7	.63	.57	.76
Lower left corner. . . .		.50	.37	.76
	1	...	...	.83
	2	...	...	.82
	3	...	.30	.75
	4	...	...	.76
	5	...	...	.73
Mean		10.57	10.42	10.72

The surfaces of the plates were scoured clean.

The plates were arranged on chords of a circle with the gun pivot as the centre, and the muzzle of the gun 28 feet distant from the centre of the plate toward which it was pointed, the axis of the gun being then normal to the surface of each plate.

The gun was a 6-inch B. L. R., Mark III., 35 calibers long, mounted on a service centre-pivot carriage. The charge used was 44½ lbs. for each round; brown prismatic powder manufactured by Messrs. Dupont. The striking velocity was 2075 feet per second.

The projectiles were all Holtzer 6-inch Armor-piercing Shell, with ogival of 2 calibers radius, and were brought up to the standard weight of 100 lbs. by filling them with sand and fragments of iron. These fragments of iron weighed about 2 oz. each.

The gun was mounted on a heavy wooden platform protected by a structure of timber roofed with iron plates and a pile of sand-bags in front, through which the muzzle projected.

The pointing was done by means of central cross-hair sights in the axis of the bore.

Bomb-proofs had been erected at convenient places on the grounds. The one nearest the gun, at a distance of 50 feet, protected the firing party. The gun was fired by means of friction primer and a long lanyard.

The Board caused photographs to be taken of each plate before and after each shot; of all three plates in a group after four shots each, and, also, after five shots each; of the recovered projectiles, and of such fragments of plate as could be identified.

At 11 A. M. the Board began the firing trial.

ROUND 1.

1ST SHOT AT THE STEEL PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the bottom and 24 ins. from the right-hand edge of the plate. The projectile entered and remained in the plate, with its base projecting 6.50 ins. and its body apparently intact. A bulge, 1 inch high and 17.5 ins. diameter, was raised on the face of the plate, with a well-developed fringe projecting one inch. The visible portion of the hole in the plate was funnel-shaped, extending to a depth of 3 or 4 ins. Six short radial surface cracks were produced in the bulge. One small piece of fringe scaled off.

The side plates were uninjured; one bolt slightly started. The backing was undisturbed and no bolts were started. The rotating band was stripped off the projectile. Its base plug could still be easily turned.

(Photograph No. 4.)

ROUND 2.

1ST SHOT AT THE COMPOUND PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the right-hand edge and 24 ins. from the bottom of the plate. The projectile perforated the plate and lodged in the backing, with its base at a distance of 21.5 ins. from the face of the plate. Eight fine radial cracks were produced, varying in length from 24.5 ins. to 55 ins. from the centre of the hole. One of these extended to the right edge of plate, at which point it seemed to extend through the steel face. The right-hand corner of the plate, along the through crack mentioned above, was set out to a distance of 0.10 in. The steel face around the hole was scaled off to a diameter of from 14.5 to 19 ins., and to a depth of from 1.3 to 2.25 ins. The interior of the shot-hole showed a rough surface.

The side plates were uninjured. Two bolts of right side plate near point of impact were slightly started. One tie-bolt of the backing, about 8 ins. from the point of impact, was started 5 ins. to the rear. The rear side of bolt heads in first row of vertical bolts started $\frac{1}{10}$ inch from the braces.

The two inner lower braces of the backing were started upward and backward 0.25 in. The projectile remained buried in the backing with its base visible through the hole.

(Photograph No. 5.)

ROUND 3.

1ST SHOT AT THE NICKEL STEEL PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the right-hand edge and 24 ins. from the bottom of the plate. The body of the projectile remained in the plate. The rear end, 7.5 ins. long, broke off at a distance of 4 ins. in from the face of the plate and rebounded 30 feet to the front. A front bulge was raised, 17 ins. diameter and 1.25 ins. high. There was no fringe.

Two short radial surface cracks were produced in the bulge. A small piece of the bulge, one inch deep, was scaled off from the side of the shot-hole.

The side plates were uninjured. The head of one bolt was split in two.

The bolt in backing nearest the point of impact was driven 30 ins. to the rear. The backing was undisturbed.

(Photographs Nos. 6 and 17.)

ROUND 4.

2D SHOT AT THE STEEL PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the left-hand edge and 24 ins. from the bottom of the plate. The projectile penetrated to a depth of 12 inches and rebounded entire to a distance of 26 feet to the front and 3 feet to the right. It was shortened 0.10 in. A front bulge was raised, 18.5 ins. diameter and 1 in. high, with a well-developed fringe projecting 0.75 in. Seven short radial cracks were developed in the bulge, two of them being connected by two short surface hair cracks. One small piece of fringe scaled off. The shot-hole was regular with a smooth surface, and showing star-shaped cracks at inner extremity.

The side plates were uninjured. Two bolts were started. One nut of a side plate bolt was broken off. The backing was undisturbed.

(Photographs Nos. 7 and 17.)

ROUND 5.

2D SHOT AT THE COMPOUND PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the left-hand edge and 24 ins. from the bottom of the plate. The projectile perforated the plate and lodged in the backing, with its base visible at a distance of 15 ins. from the face of the plate. The steel face was scaled off the plate around the shot-hole, irregularly, to an average diameter of 14 ins. and depth of 1.25 ins.

Six radial cracks were produced, all extending to the edges of the plate and apparently quite deep. A surface crack was produced about 3.5 feet above lower edge of plate, extending nearly across the plate.

Two connecting radial cracks, produced by the first shot, deepened and were extended entirely across the plate through both shot-holes, throwing out the lower part of the plate from

0.6 in. to 1.8 ins. Where this crack reached the right edge of the plate, the steel face showed a vertical curved fracture of a minimum thickness of 0.3 in. and separated 1.9 ins. at the top.

The interior surface of the shot-hole was rough and broken, showing a disintegration of the metal, many small loose fragments of which were lying in the hole. The cracks developed by the preceding shot were all increased in size, the lower part of the plate being much racked.

The side plates were uninjured. Two bolts were slightly started.

The backing showed but slight set-back. One tie-bolt in backing nearest impact was driven 4 ins. to the rear. The rear side of bolt heads of first vertical row were started 0.10 in. from the braces.

(Photograph No. 8.)

ROUND 6.

2D SHOT AT THE NICKEL STEEL PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the left-hand edge and 24 ins. from the bottom of the plate. The projectile penetrated and remained in the plate apparently intact, its base projecting 1.6 ins. The rotating band was still in place, but sheared flush with the body of the shell.

A front bulge was thrown up, 16 ins. in diameter and 1.10 ins. high. A piece was scaled off for about two-thirds the circumference of the bulge, of an average diameter of 12.55 ins. and average depth of 1.10 ins.

The side plates were uninjured, two bolts slightly started. The backing was uninjured. The tie-bolt nearest the point of impact was driven 12 ins. to the rear.

(Photograph No. 9.)

ROUND 7.

3D SHOT AT THE STEEL PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the right-hand edge and 24 ins. from the top of the plate. The projectile penetrated to a depth of 12.5 ins. and rebounded entire to a distance of 30 ft. It was shortened 0.14 in., and the diameter of the bourrelet was increased 0.01 in.

A front bulge was found, 18.5 ins. in diameter and 1 in. high, with a well-developed fringe projecting 1 in. Five short radial surface cracks were developed in the bulge, and two small pieces of the fringe were scaled off. The shot-hole was smooth and regular, showing star-shaped cracks at its inner extremity.

The side plates were uninjured, one piece of bolt 7 ins. long was broken off and thrown out to the front. The backing and its bolts were undisturbed.

(Photographs Nos. 10 and 17.)

ROUND 8.

3D SHOT AT THE COMPOUND PLATE.

Gun,	6″ B. L. R.	Elevation, — 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the right-hand edge and 24 ins. from the top of the plate. The projectile perforated the plate and lodged in the backing, with its base 23.75 ins. from the face of the plate.

Ten deep radial cracks were produced, some of them being connected by cross-cracks. A large piece of steel face in upper right-hand corner was slightly separated from the wrought iron back, and a smaller piece was in the same condition below the shot-hole.

Old cracks in lower part of plate were increased in size, and the face of the plate was quite shattered.

The interior surface of the shot-hole was rough and broken, showing disintegration of the surrounding metal, many small fragments of which had been shaken off and were lying in the hole.

The side plates were not injured. The nuts of five bolts in the left side plate were unscrewed from 0.25 in. to 0.50 in.

The backing was uninjured.

(Photograph No. 11.)

ROUND 9.

3D SHOT AT THE NICKEL STEEL PLATE.

Gun,	6″ B. L. R	Elevation,	2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity,	2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy,	2988 ft.-tons.

The point of impact was 24 ins. from the right-hand edge and 24 ins. from the top of the plate. The projectile penetrated and remained in the plate apparently intact, its base projecting 4.5 ins., and its rotating band half torn off. A front bulge was raised, 18 ins. in diameter and 1.5 ins. high.

Two very short radial surface cracks were produced in the bulge. Two small pieces scaled out of bulge. The side plates were uninjured; the bolt heads were slightly bent.

The backing was undisturbed, and no bolts were started.

(Photograph No. 12.)

ROUND 10.

4TH SHOT AT THE STEEL PLATE.

Gun,	6″ B. L. R.	Elevation, 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the left-hand edge and 24 ins. from the top of the plate. The projectile penetrated to a depth of 12.5 inches and rebounded, breaking into three large and several small pieces. The head was entire, the body in halves, the transverse break at 7 ins. from the base of shell.

A front bulge was raised, 17 ins. in diameter and 1 in. high, with a well-developed fringe projecting 1 in.

Six short radial surface cracks were produced in the bulge, and one small piece of the fringe was scaled off. The surface of shot-hole was smooth and regular, showing star-shaped cracks at its inner extremity.

The side plates were uninjured.

The backing was undisturbed. One bolt, broken by previous shot, was driven to the rear 2 ins.

(Photographs Nos. 13 and 17.)

ROUND 11.

4TH SHOT AT THE COMPOUND PLATE.

Gun,	6″ B. L. R.	Elevation, 2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity, 2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy, 2988 ft.-tons.

The point of impact was 24 ins. from the left-hand edge and 24 ins. from the top of plate. The projectile perforated plate and backing, breaking into three large and several small pieces. The largest piece passed over the earth backing, and lodged in the butt 60 feet away.

Three deep cracks were developed below shot-hole. All the steel face above this and the preceding shot-hole separated from the wrought-iron back, and the greater part of it was thrown off in seven large, and many small fragments, the larger fragments weighing, respectively, 29, 58, 92, 125, 157, 178, and 380 lbs.

A part of the steel face below the preceding shot-hole separated from the wrought-iron back and was thrown off.

All previous cracks widened.

That part of the wrought-iron back which was exposed on the upper part of the plate showed a rough, broken appearance and contained three narrow cracks. The shot-hole was very rough on the interior surface, showing much disintegration of the metal, with small fragments of which it was nearly filled.

The remainder of the plate was badly racked, and showed 17 large cracks through steel face. The side plates were uninjured.

There was an irregular hole torn in the backing by the shot. No bolts were started.

(Photographs Nos. 14, 16, and 17.)

ROUND 12.

4TH SHOT AT THE NICKEL STEEL PLATE.

Gun,	6″ B. L. R.	Elevation,	2° 50′.
Projectile,	Holtzer A.-P. Shell, 100 lbs.	Striking velocity,	2075 f. s.
Charge,	44½ lbs. brown prism.	Striking energy,	2988 ft.-tons.

The point of impact was 24 ins. from the left-hand edge and 24 ins. from the top of the plate. The projectile broke 3.5 ins. from face of plate, and 6.5 ins. from its base, its head remaining in the plate. The rear half rebounded 30 feet, burying itself in the sand-bags around the gun.

A front bulge was raised, 16 ins. in diameter and 1 in. high. One fine crack was developed in the upper part of the bulge.

The visible interior surface of the hole was smooth and regular.

The side plates were uninjured, bolt heads slightly bent. The backing was undisturbed, and no bolts were started.

(Photographs Nos. 15 and 17.)

After the preceding twelve rounds had been fired, the Board adjourned for two days, until an 8-inch gun, with which it was decided to continue the firing, could be mounted. The firing with this gun took place on Monday, September 22, 1890.

The gun was mounted on the same platform as the 6″, with its pivot 6½ feet to the rear of the 6″ pivot. The muzzle of the gun was 30 feet distant from the plates.

The charge was 85 lbs. of brown prismatic powder, made by Dupont. The striking velocity was 1850 feet per second.

The projectiles were Firth Armor-piercing Shell, weighted to 210 lbs. by filling them with sand.

ROUND 13.

5TH SHOT AT THE STEEL PLATE.

Gun,	8″ B. L. R.	Elevation, 0° 00′.
Projectile,	Firth A.-P. Shell, 210 lbs.	Striking velocity, 1850 f. s.
Charge,	85 lbs. brown prism.	Striking energy, 4988 ft.-tons.

The point of impact was at the centre of the plate. The projectile penetrated to a depth of 15 ins. and rebounded, broken in three large pieces. A front bulge was raised, 21 ins. in diameter and 1 in. high. There was no fringe. A piece scaled off from the lower right-hand edge of hole radially for 5 ins.

Four through cracks radiating from the shot-hole were developed, two above and two below, each one extending diagonally through one of the 6″ shot-holes to top and bottom of face respectively, and forming an irregularly-shaped X. These cracks above the centre hole varied in width from 0.25 to 0.50 in., and below the centre hole, from 0.16 to 0.50 in.

The upper right-hand crack reached the top at a point 13 ins. from the side. The upper left-hand crack reached the top 5.5 ins. from the side. The lower right-hand crack reached the bottom 13.25 ins. from the side, and the lower left-hand crack reached the bottom 8 ins. from the side of the plate.

The side plates were uninjured and the bolts intact.

The backing was driven back bodily 0.10 in.

(Photographs Nos. 19, 22, and 23.)

ROUND 14.

5TH SHOT AT THE NICKEL STEEL PLATE.

Gun,	8″ B. L. R.	Elevation,	0° 00′.
Projectile,	Firth A.-P. Shell, 210 lbs.	Striking velocity, 1850 f. s.	
Charge,	85 lbs. brown prism.	Striking energy, 4988 ft.-tons.	

The point of impact was the centre of the plate. The projectile entered and broke 5.25 ins. from the face of plate, part of the head remaining in the hole.

A front bulge was raised, 16.5 ins. in diameter and 0.25 in. high. The circumference of the hole was scaled out to the following radial distances from the centre:

At top,	7	ins. out,	maximum	depth,	4 ins.
At right side,	6	ins.	"	"	2 ins.
At bottom,	6.5	ins.	"	"	2 ins.
At left side,	7.25	ins.	"	"	4 ins.

A hole of considerable length was visible on the side of the interior of the hole, between the projectile and interior surface of the plate.

There were no cracks visible on the plate.

The side plates were uninjured, and no bolts were started.

The front timber of the backing, in the line of the shot-hole, was apparently broken in two.

The fragments of projectile that were recovered are shown in the photograph.

(Photographs Nos. 20, 22, and 23).

ROUND 15.

5TH SHOT AT THE COMPOUND PLATE.

Gun,	8″ B. L. R.	Elevation,	0° 00′.
Projectile,	Firth A.-P. Shell, 210 lbs.	Striking velocity,	1850 f. s.
Charge,	85 lbs. brown prism.	Striking energy,	4988 ft.-tons.

The point of impact was the centre of the plate. The projectile perforated the plate and backing, and disintegrated much of the metal about the hole. Most of the front plate was scaled off in 24 large and a great number of small pieces, the larger pieces varying in thickness from 3.75 to 5.50 ins.

Parts of the plate were left complete along each edge, as shown in the photographs, but much of it separated, some of the fragments of the steel being nearly on the point of falling off. The exposed wrought-iron back showed 18 cracks of varying length.

The metal about the interior of the hole was rough and broken. The wrought-iron surface was rough and irregular. The metal around all shot-holes showed considerable disintegration. Several concentric cracks appeared in the wrought-iron back about the 8″ shot-hole.

The side plates were uninjured.

The projectile broke an irregular hole through the backing, but all damage was local.

The shell was recovered entire, having penetrated the earth backing about 15 ft. It was shortened 0.24 in., and the diameter of the bourrelet was increased 0.015 in.

(Photographs Nos. 21, 22, and 23.)

The Board then adjourned until the plates could be removed from the backing so as to expose to view their rear faces.

The Board met at the Naval Ordnance Proving Ground on October 10, 1890, and examined the backs of the plates and the fronts of the backing, with the following results:

BACK OF STEEL PLATE.

(Photographs Nos. 24 and 24a.)

No. 1 Shot.	Back bulge 3.5 ins. high and 16 ins. diameter.
No. 2 Shot.	Back bulge 3.0 ins. high and 15 ins. diameter.
No. 3 Shot.	Back bulge 2.6 ins. high and 16 ins. diameter, with a piece broken out.
No. 4 Shot.	Back bulge 2.6 ins. high and 15 ins. diameter.
No. 5 Shot.	Back bulge 6.25 ins. high and 22 ins. diameter, with two pieces broken out.

Diagonal cracks from front of plate all through to back.

BACKING OF STEEL PLATE.

(Photograph No. 25.)

No. 1 Shot.	Indented 2.75 ins.
No. 2 Shot.	Indented 2.40 ins.
No. 3 Shot.	Indented 2.00 ins., two pieces embedded in the backing.
No. 4 Shot.	Indented 2.40 ins.
No. 5 Shot.	Indented 5.25 ins., and one piece embedded in the hole.

BACK OF NICKEL STEEL PLATE.

(Photographs Nos. 26 and 26a.)

No. 1 Shot.	Back bulge 5 ins. high and 21 ins. diameter.
No. 2 Shot.	Back bulge 6 ins. high and 21 ins. diameter.
No. 3 Shot.	Back bulge 4 ins. high and 19 ins. diameter.
No. 4 Shot.	Back bulge 4 ins. high and 18 ins. diameter.
No. 5 Shot.	A crater in back of plate was formed, of an average depth of 3.5 ins. and 21 ins. diameter.

BACKING OF NICKEL STEEL PLATE.

(Photograph No. 27.)

No. 1 Shot.	Indented 5.25 ins.
No. 2 Shot.	Indented 4.75 ins.
No. 3 Shot.	Indented 3.50 ins.
No. 4 Shot.	Indented 3.50 ins.
No. 5 Shot.	A hole 10½ ins. deep in the wood, and 6 ins. deep to a fragment of metal left in the backing from the crater in the plate.

BACK OF COMPOUND PLATE.

(Photographs Nos. 28 and 28a.)

No. 1 Shot.	Back bulge 6.4 ins. high and 20.5 ins. diameter.
No. 2 Shot.	Back bulge 6.25 ins. high and 18 ins. diameter.
No. 3 Shot.	Back bulge 6 ins. high and 20 ins. diameter.
No. 4 Shot.	Back bulge 7.25 ins. high and 19 ins. diameter, a large piece of plate broken out.
No. 5. Shot.	Back bulge 7.5 ins. high and 21 ins. diameter, a piece of plate broken out.

BACKING OF COMPOUND PLATE.

(Photograph No. 29.)

No. 1 Shot.	Base of projectile 11 ins. in from face of backing.
No. 2 Shot.	Base of projectile 4.75 ins. in from face of backing.
No. 3 Shot.	Base of projectile 13.1 ins. in from face of backing.
No. 4 Shot.	Through hole: piece of plate embedded in side of hole.
No. 5 Shot.	Through hole: piece of plate embedded in side of hole.

No bolts in any of the plates were injured.

NOTE.—The word "front," when applied either to the plate or fragments of plate or projectile, refers to the side of the plate toward the gun.

The swellings of the plate caused by the striking of a projectile are denominated, respectively, the "front bulge," and the "back bulge."

* * * * * * * * * *

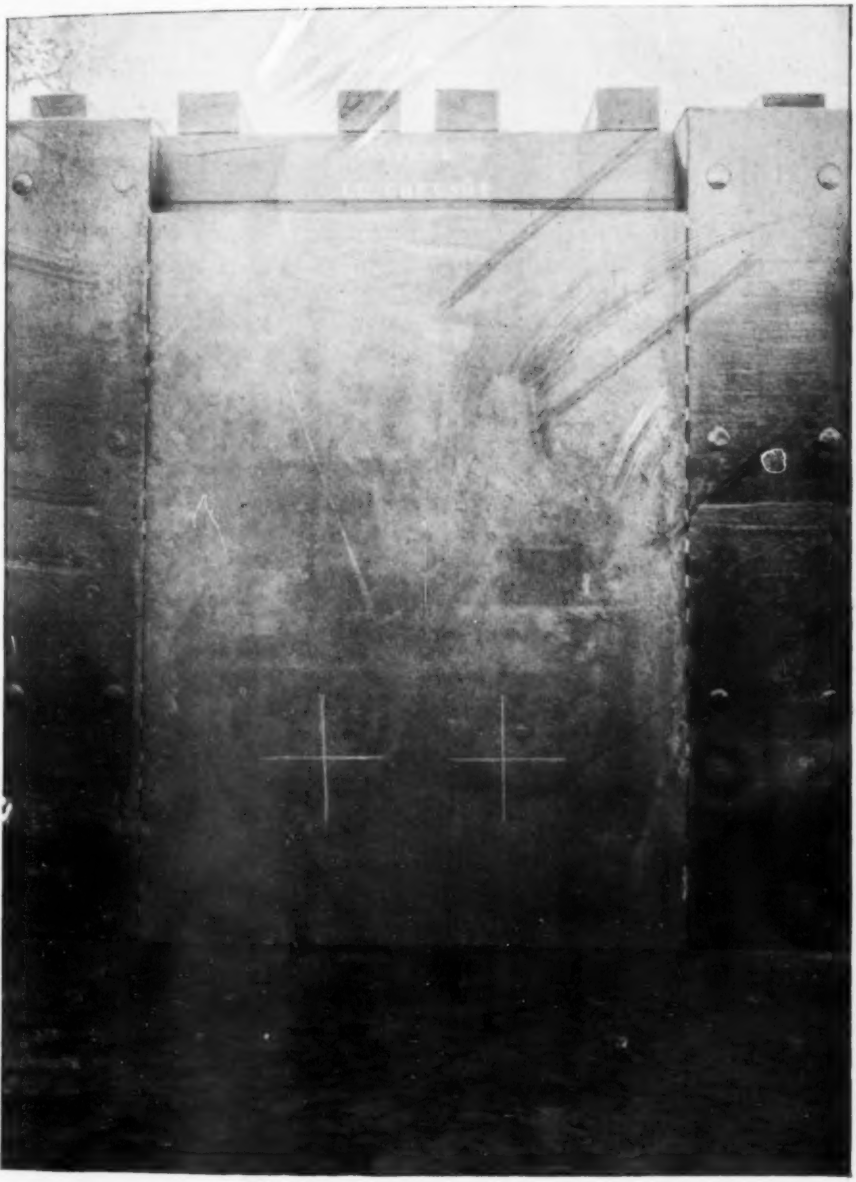
SUMMARY.

The Compound Plate was perforated by all projectiles, and its steel face was destroyed. Two of the shells passed completely through both plate and backing.

Both Steel Plates kept out all projectiles, the All-Steel Plate showing slightly greater resistance than the Nickel Steel Plate, but the former was badly cracked by the 8-inch shell, while the latter remained uncracked. The Board, therefore, places the three plates tested in the following order of "relative merit:"

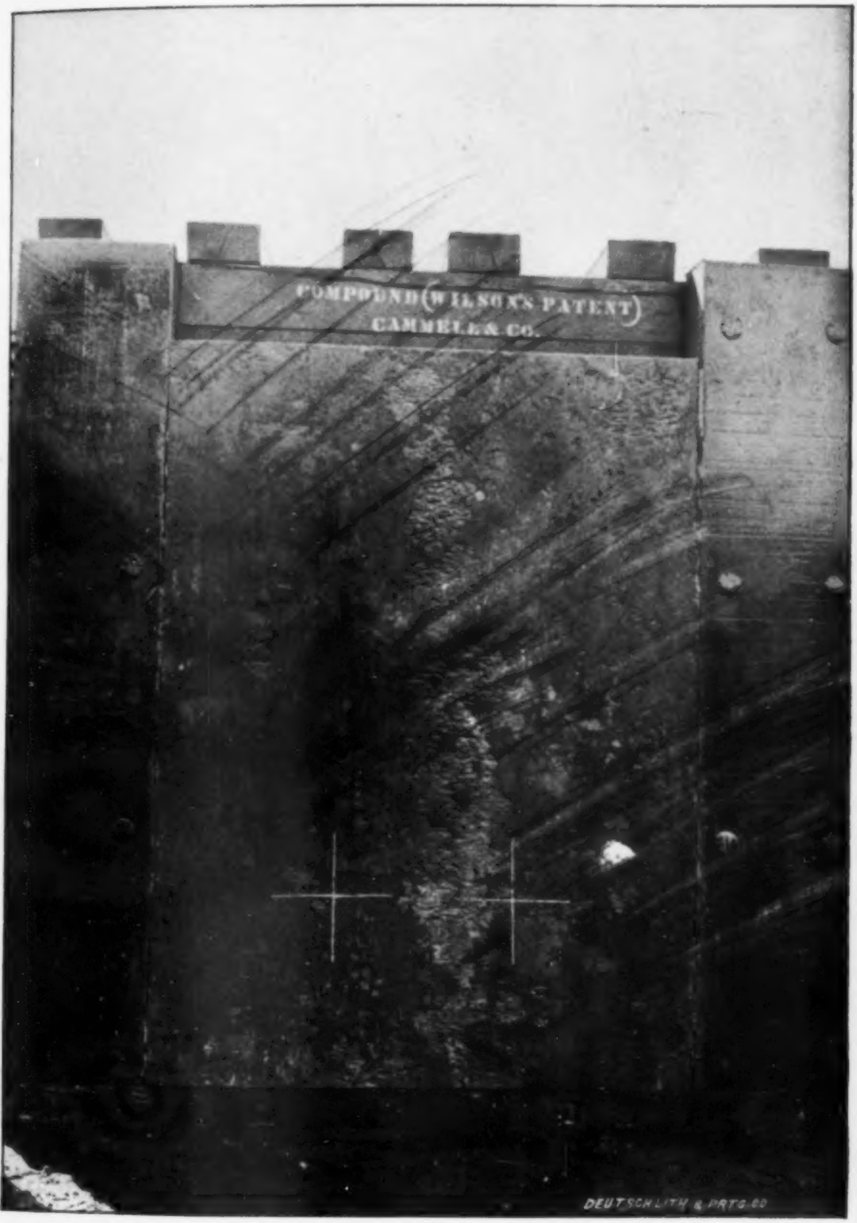
1. Nickel Steel. 2. All Steel. 3. Compound.

L. A. Kimberly,
Rear Admiral, U. S. Navy,
President of the Board.
E. O. Matthews,
Captain, U. S. Navy, Member.
W. R. Bridgman,
Commander, U. S. Navy, Member.
W. Maynard,
Lt. Comdr., U. S. Navy, Member.
J. F. Meigs,
Lieutenant, U. S. Navy, Member.
B. H. Buckingham,
Lieutenant, U. S. Navy, Member.
W. H. H. Southerland,
Lieutenant, U. S. Navy, Member.
F. F. Fletcher,
Lieutenant, U. S. Navy, Member.
Philip R. Alger,
Ensign, U. S. Navy, Member.
A. A. Ackerman,
Ensign, U. S. Navy, Member.
Robert B. Dashiell,
Ensign, U. S. Navy, Recorder.



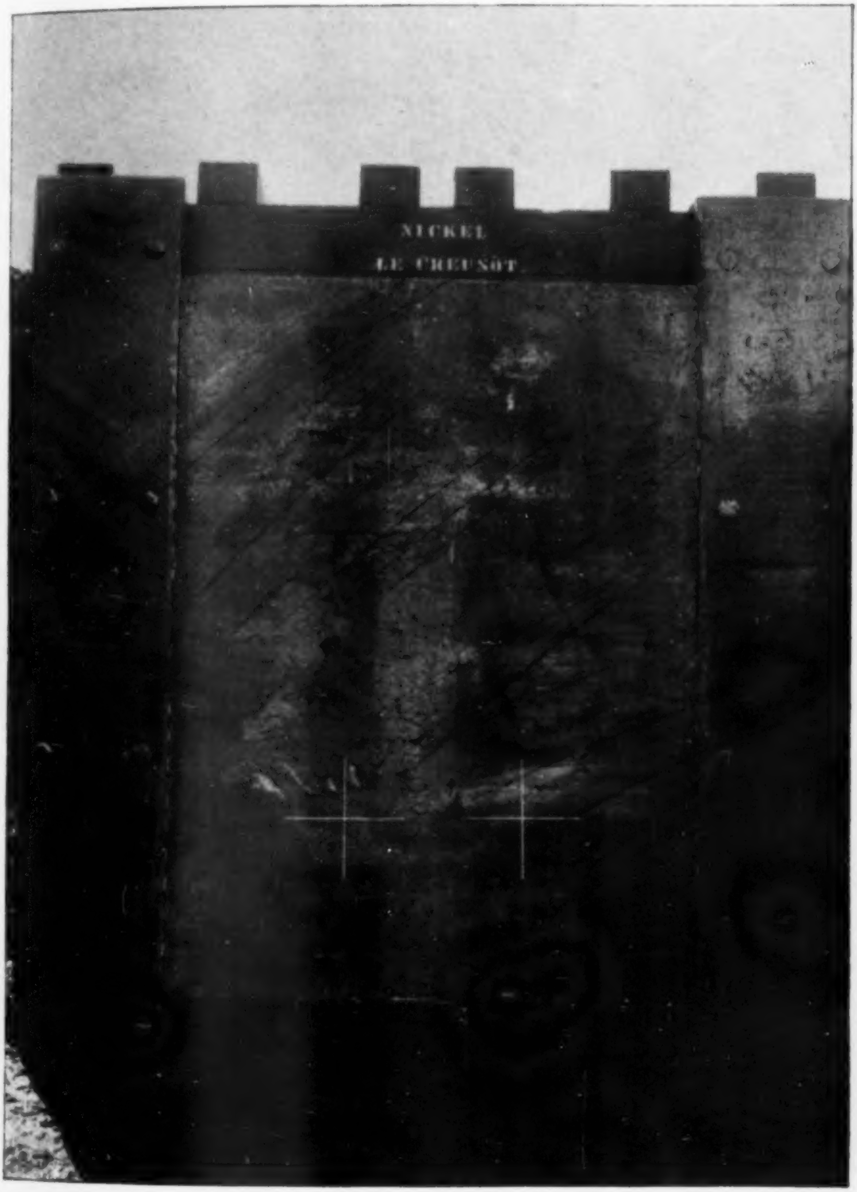
No. 1. STEEL PLATE BEFORE FIRING.

(Schneider et Cie.)


COMPOUND (WILSON'S PATENT)
CAMMELL & Co.
DEUTSCH LITH & PRTG CO

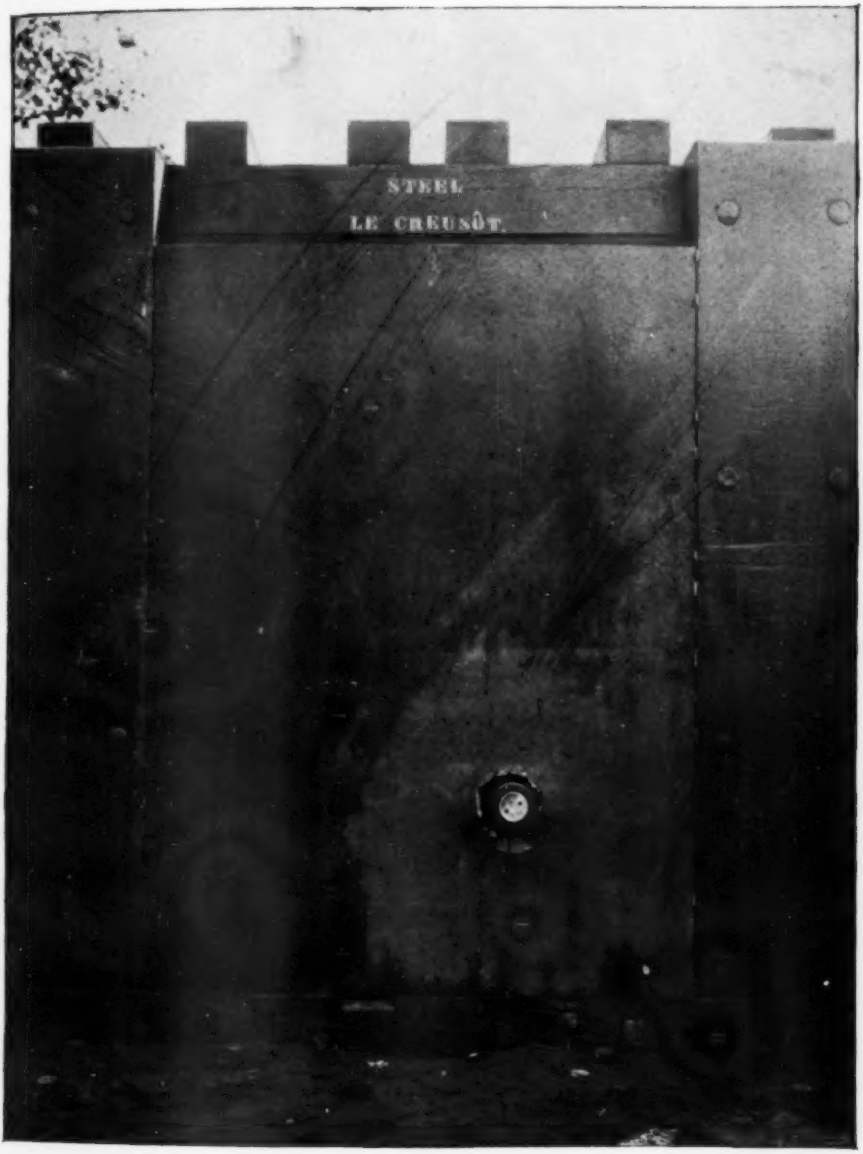
No. 2. COMPOUND PLATE BEFORE FIRING.

(Cammell & Co.)


NICKEL
LE CREUSOT

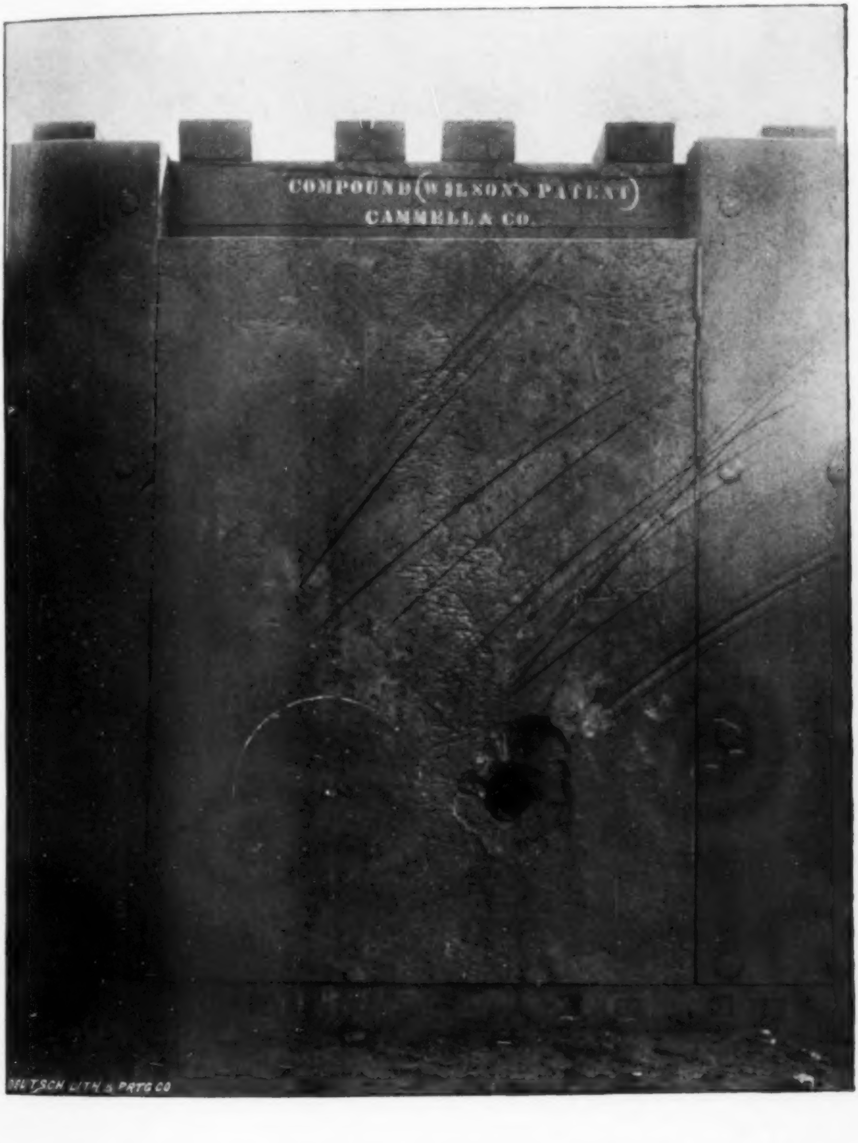
No. 3. NICKEL-STEEL PLATE BEFORE FIRING.

(Schneider et Cie.)


STEEL
LE CREUSÔT.

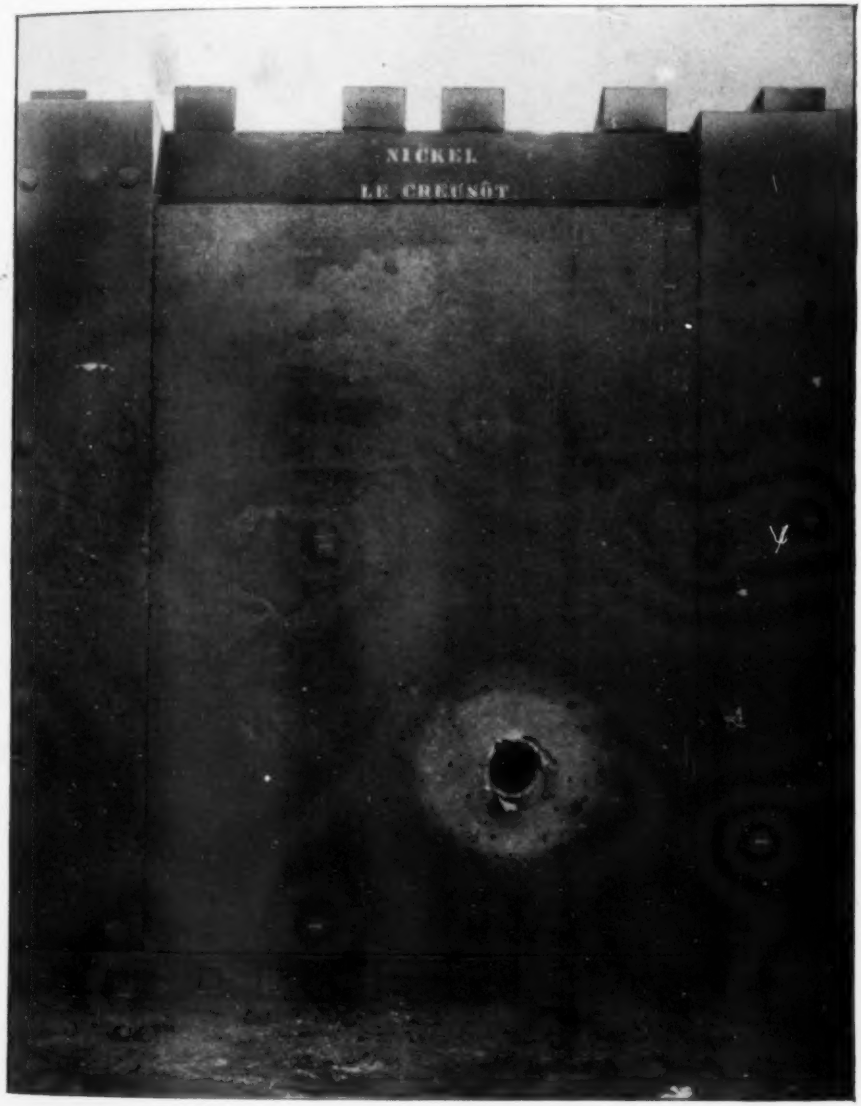
No. 4. STEEL PLATE AFTER FIRST SHOT.

(Schneider et Cie.)


COMPOUND (WILSON'S PATENT)
CAMMELL & CO.
DEUTSCH LITH & PRTG CO

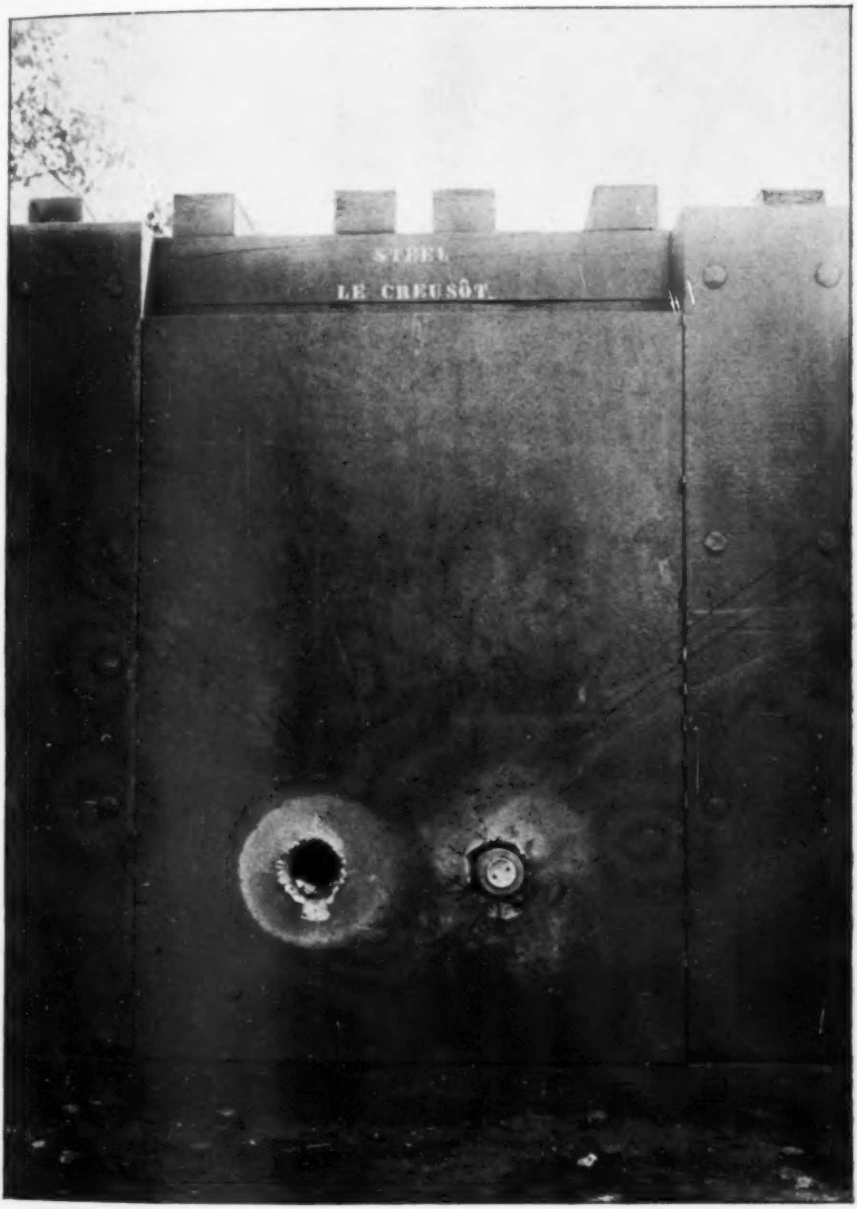
No. 5. COMPOUND PLATE AFTER FIRST SHOT.

(Cammell & Co.)


NICKEL
LE CREUSÔT

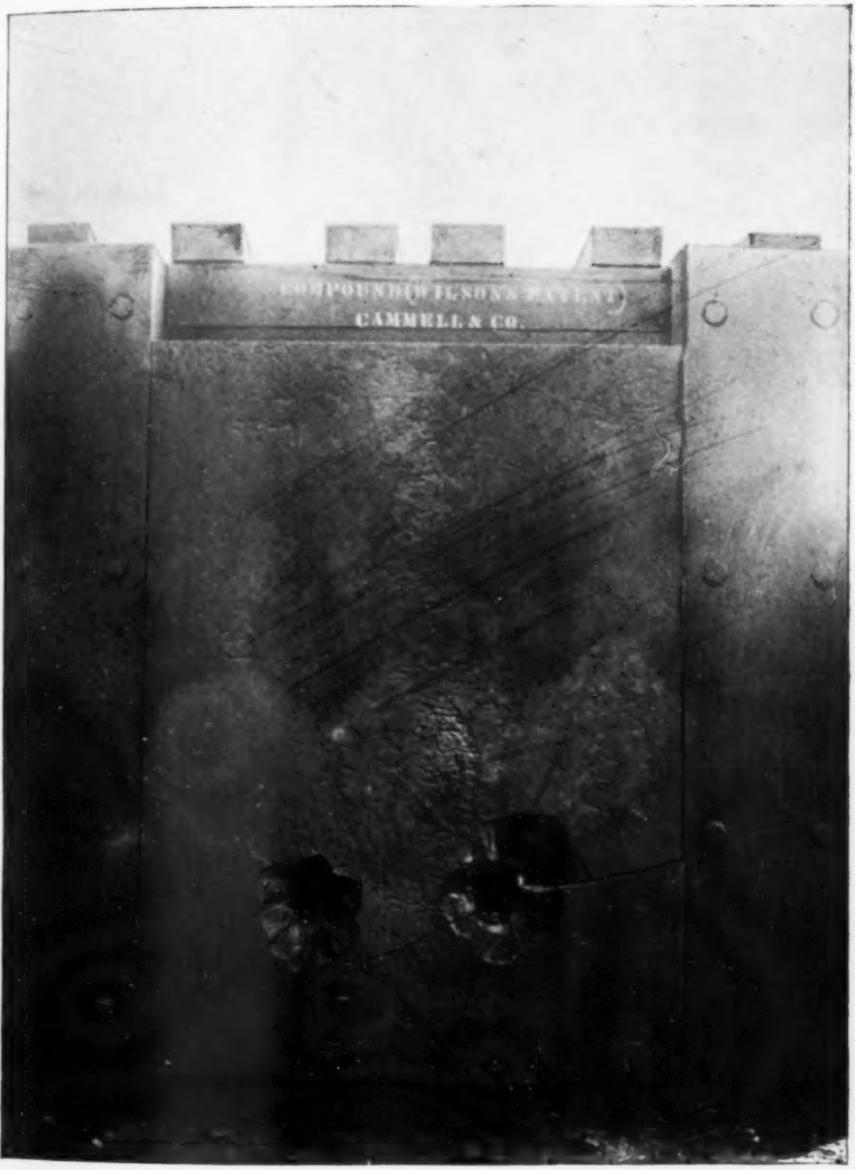
No. 6. NICKEL-STEEL PLATE AFTER FIRST SHOT.

(SCHNEIDER ET CIE.)


STEEL
LE CREUSÔT

No. 7. STEEL PLATE AFTER SECOND SHOT.

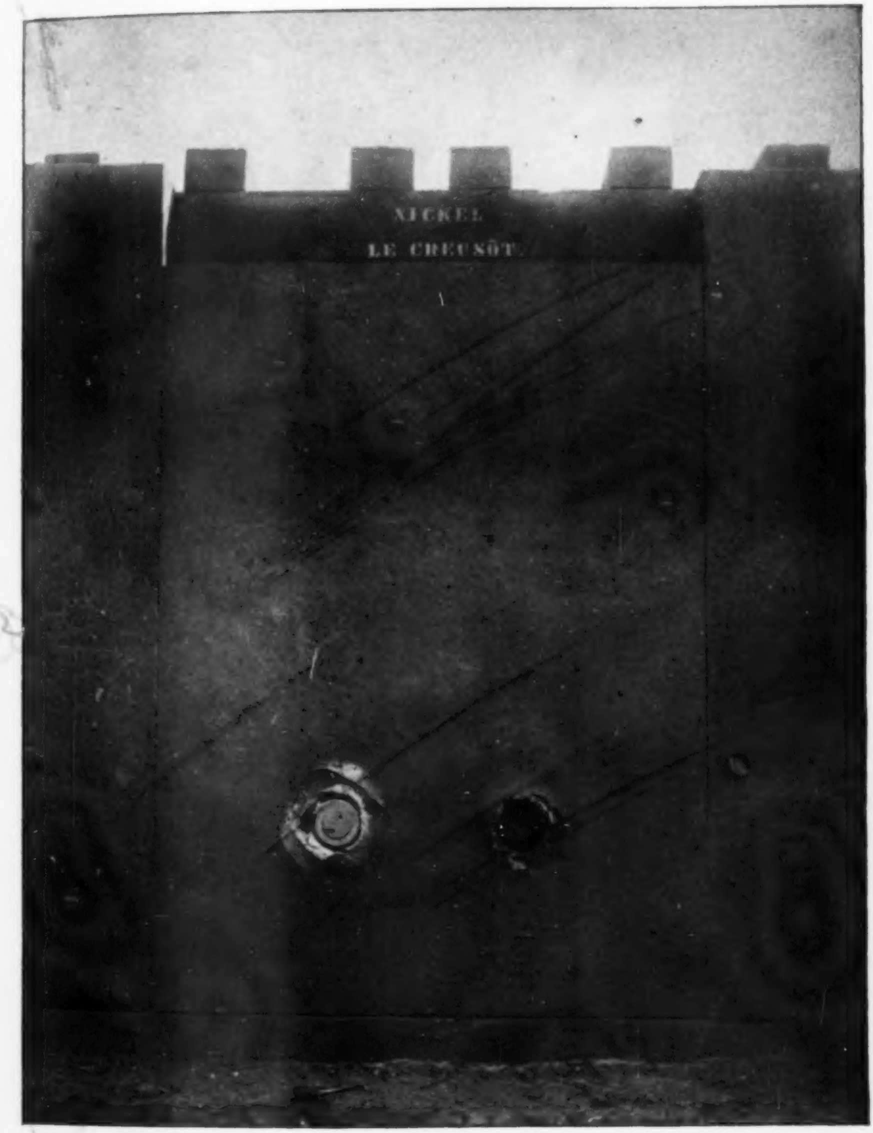
(SCHNEIDER ET CIE.)



COMPOUND (WILSON'S PATENT)
CAMMELL & CO.

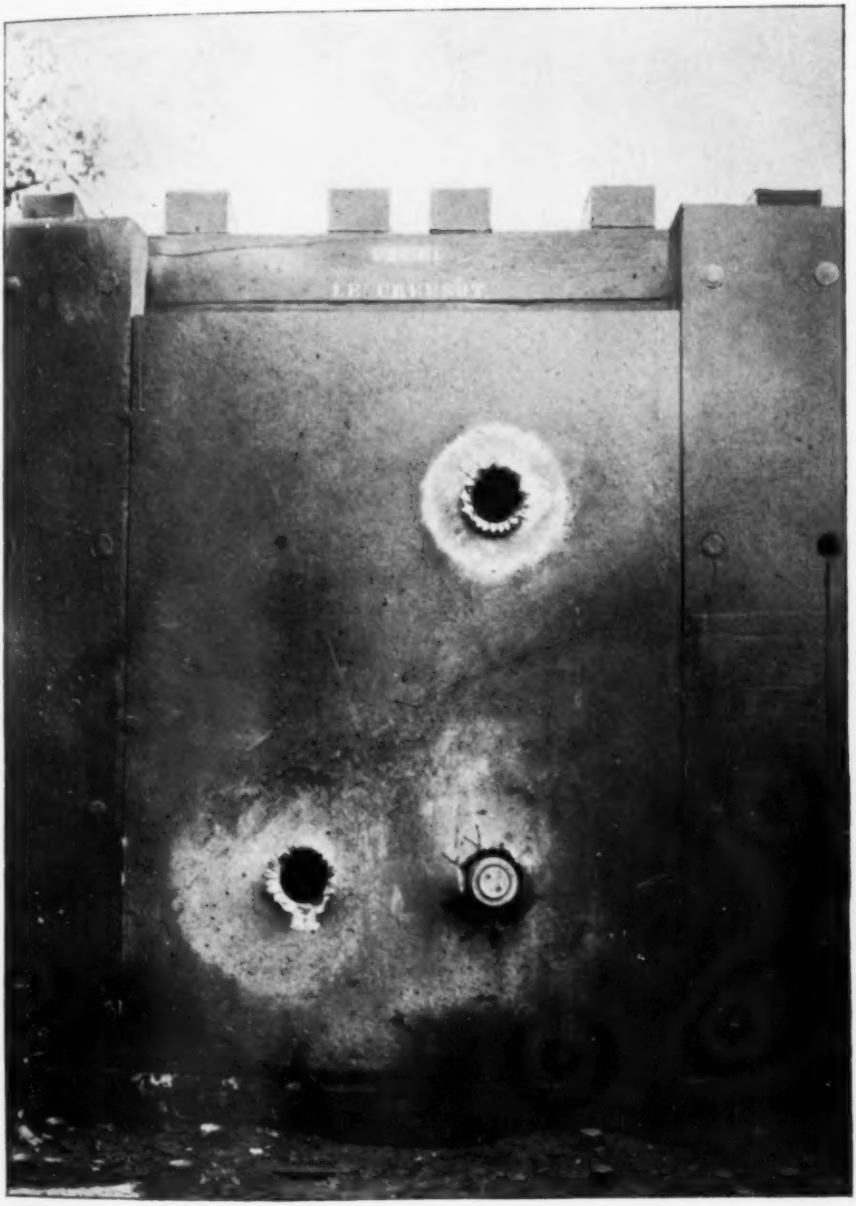
No. 8. COMPOUND PLATE AFTER SECOND SHOT.

(Cammell & Co.)


NICKEL
LE CREUSOT

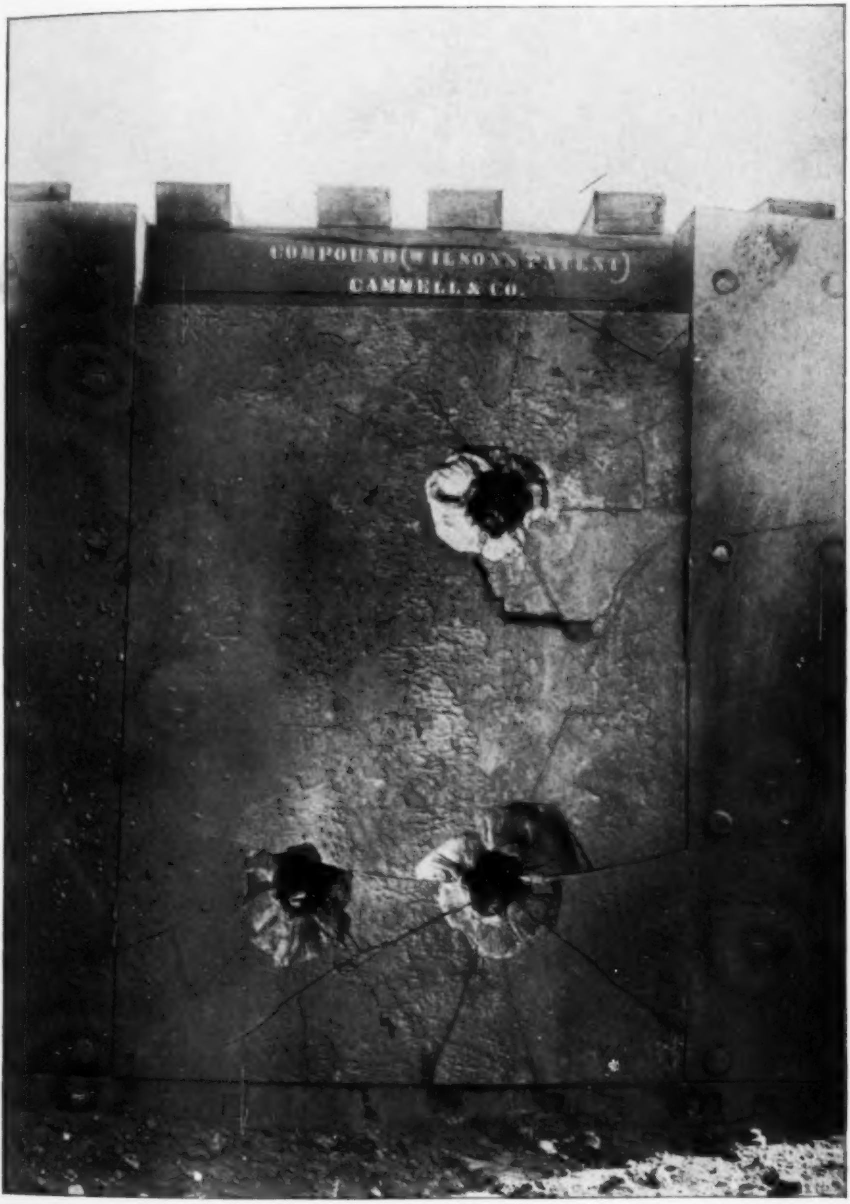
No. 9. NICKEL-STEEL PLATE AFTER SECOND SHOT.

(SCHNEIDER ET CIE.)



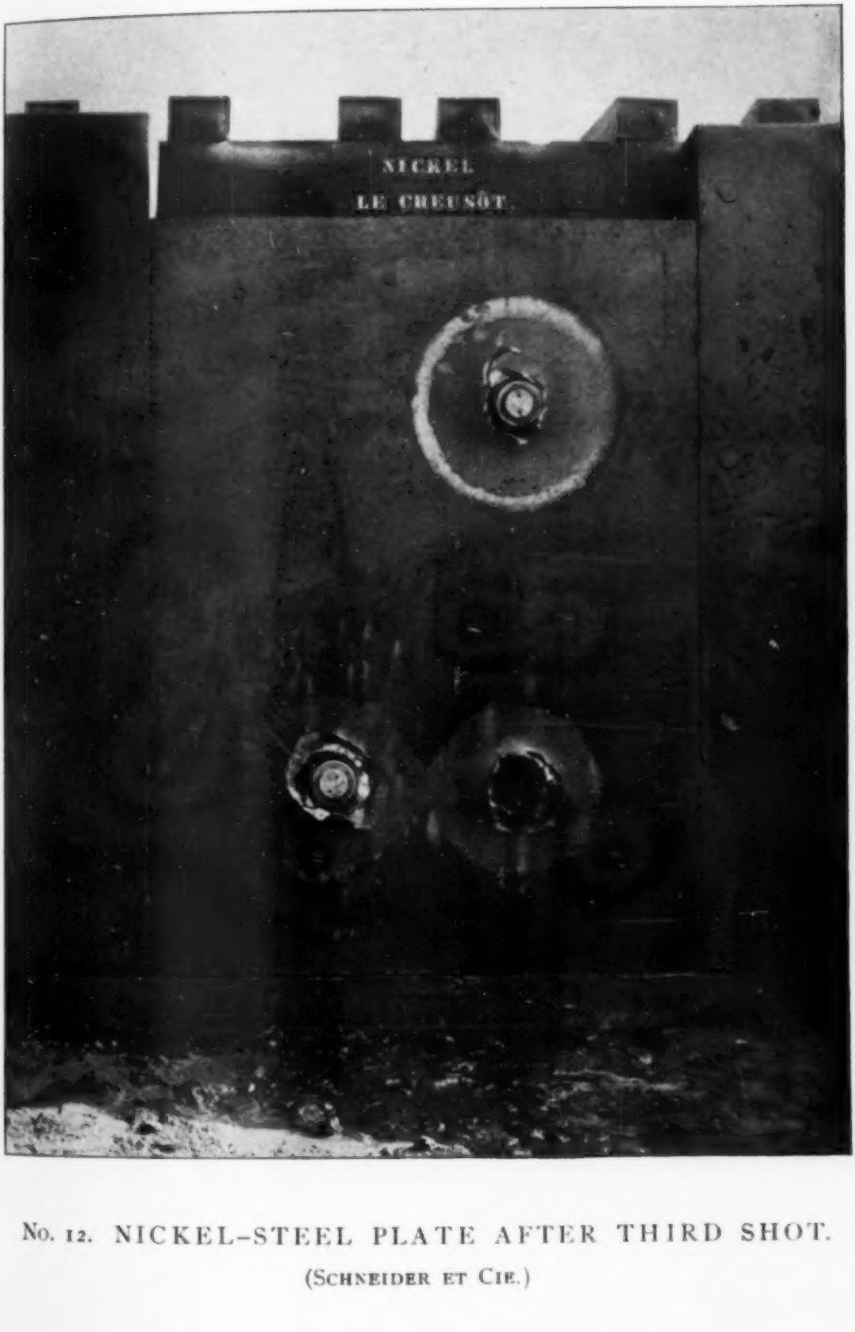
No. 10. STEEL PLATE AFTER THIRD SHOT.

(Schneider et Cie.)


COMPOUND (WILSON'S PATENT)
CAMMELL & CO.

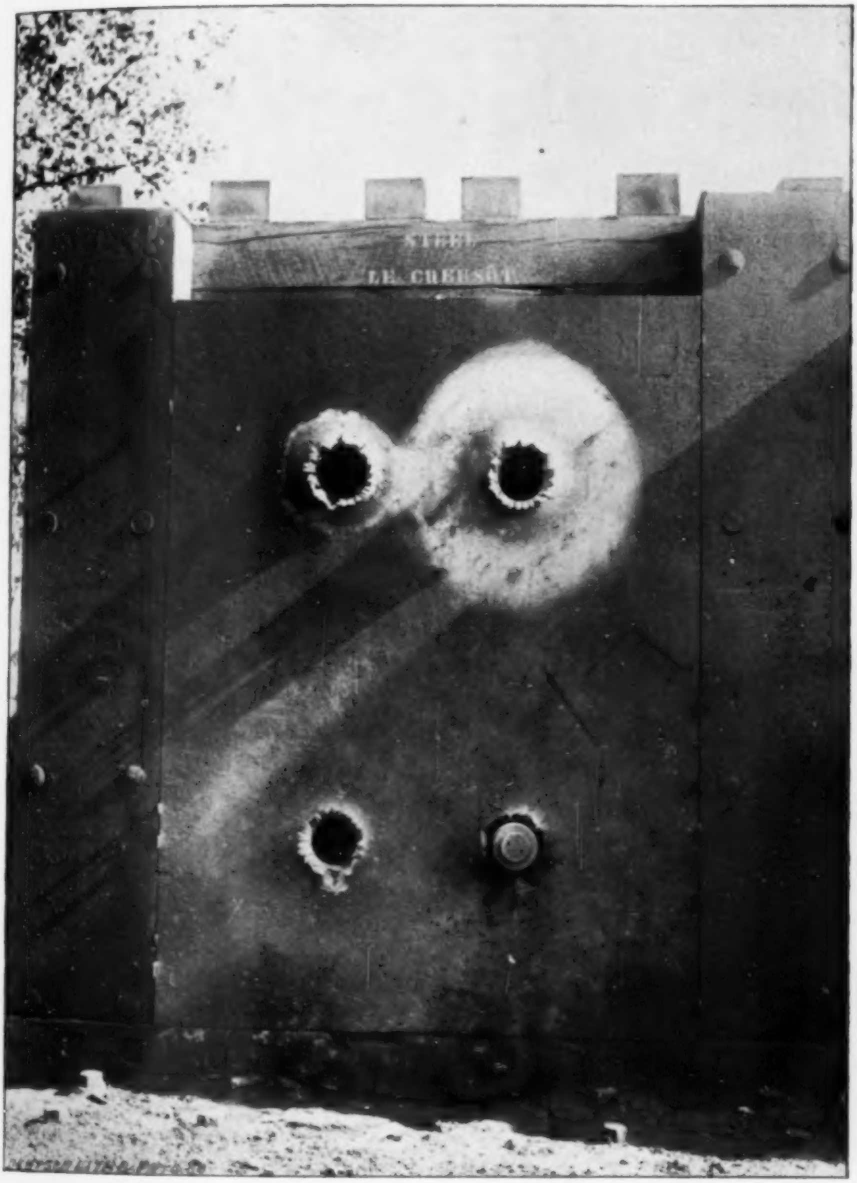
No. 11. COMPOUND PLATE AFTER THIRD SHOT.

(Cammell & Co.)


NICKEL
LE CREUSÔT

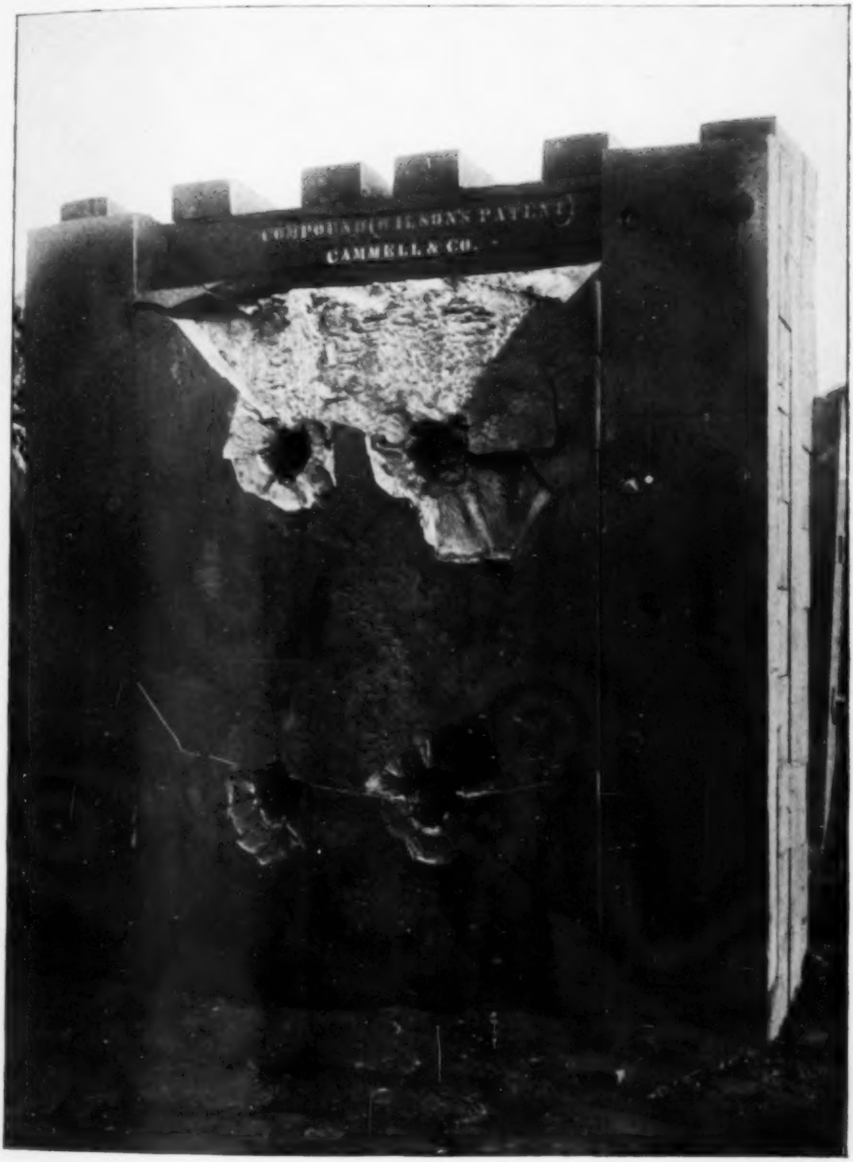
No. 12. NICKEL-STEEL PLATE AFTER THIRD SHOT.

(Schneider et Cie.)


STEEL
LE CREUSOT

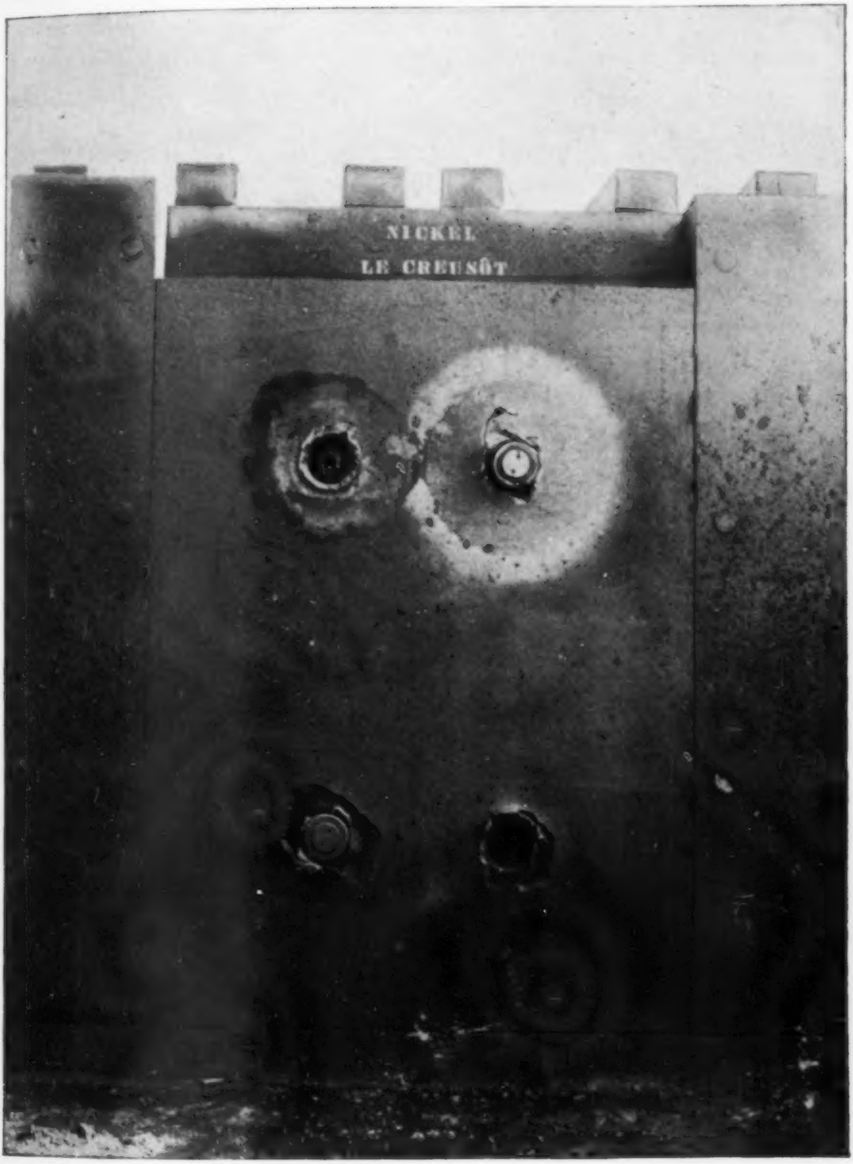
No. 13. STEEL PLATE AFTER FOURTH SHOT.

(Schneider et Cie.)


COMPOUND (WILSON'S PATENT)
CAMMELL & CO.

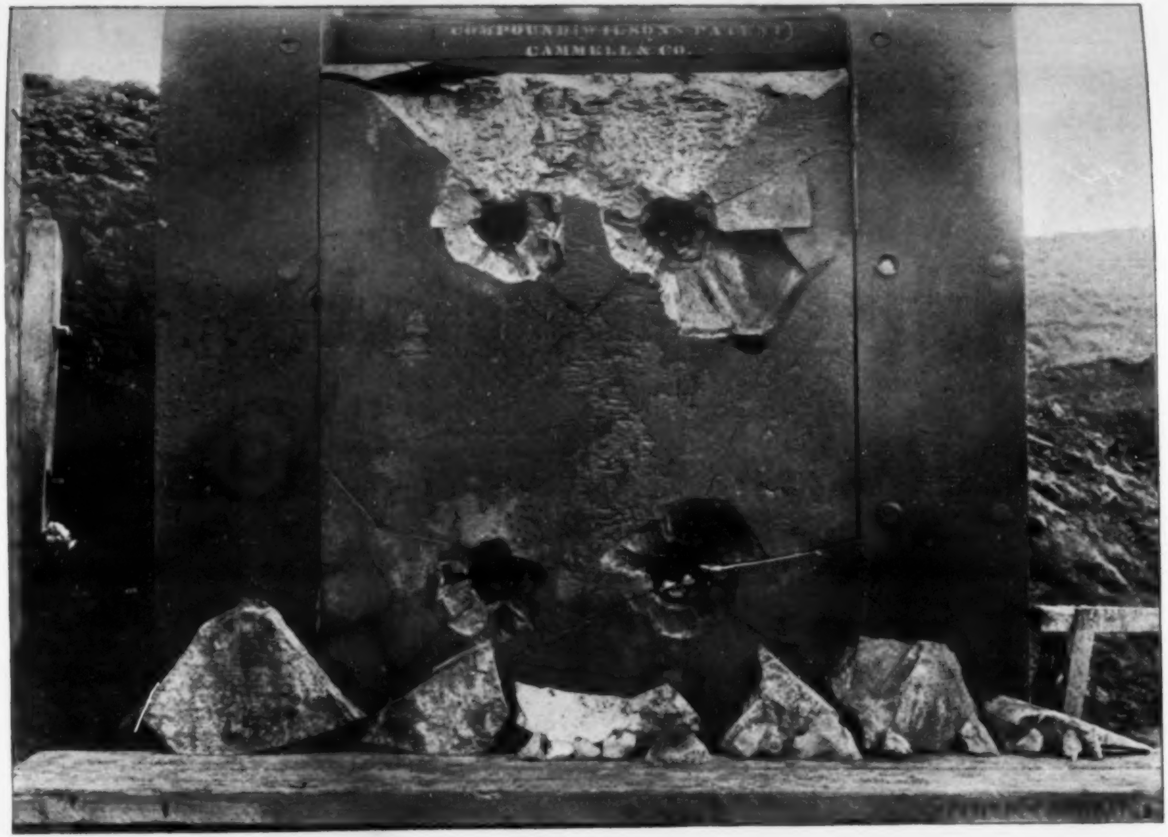
No. 14. COMPOUND PLATE AFTER FOURTH SHOT.

(Cammell & Co.)


NICKEL
LE CREUSÔT

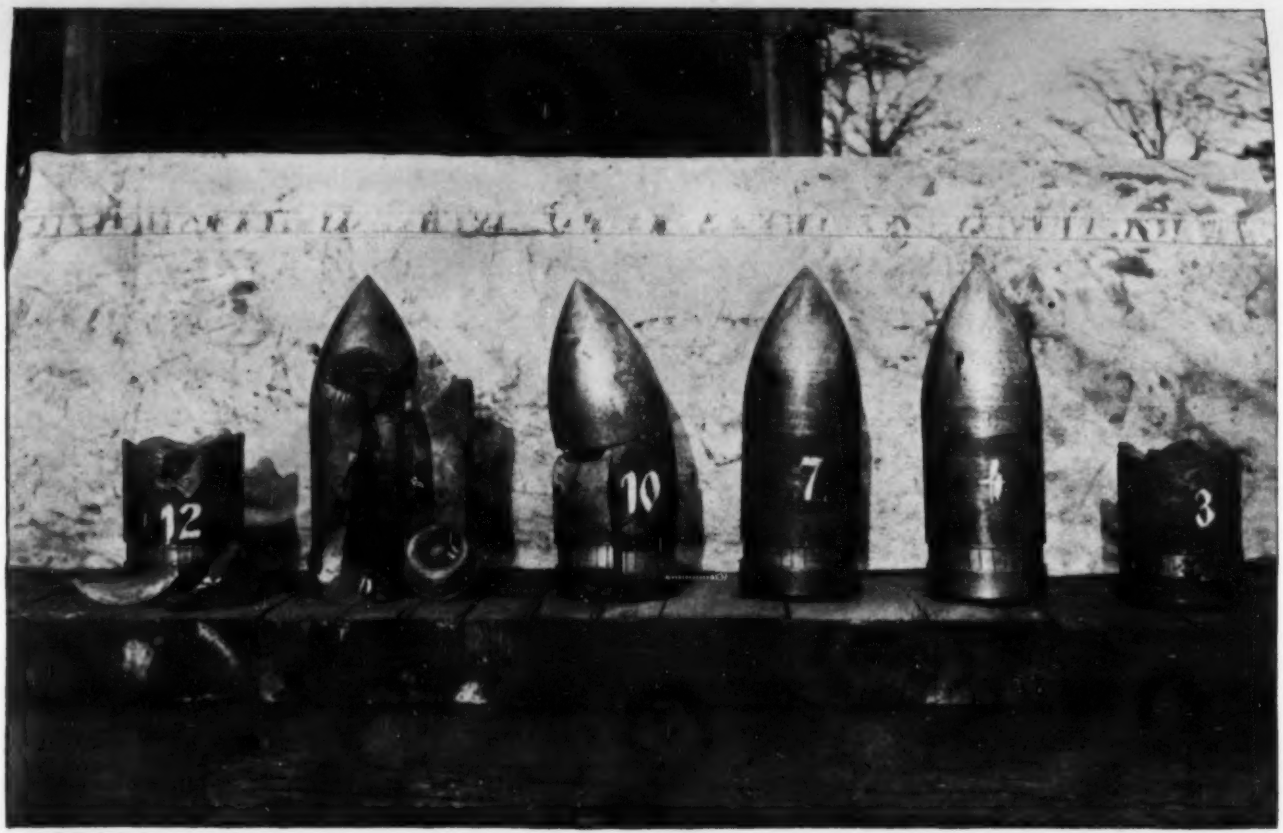
No. 15. NICKEL-STEEL PLATE AFTER FOURTH SHOT.

(SCHNEIDER ET CIE.)


COMPOUND (WILSON'S PATENT)
CAMMELL & CO.

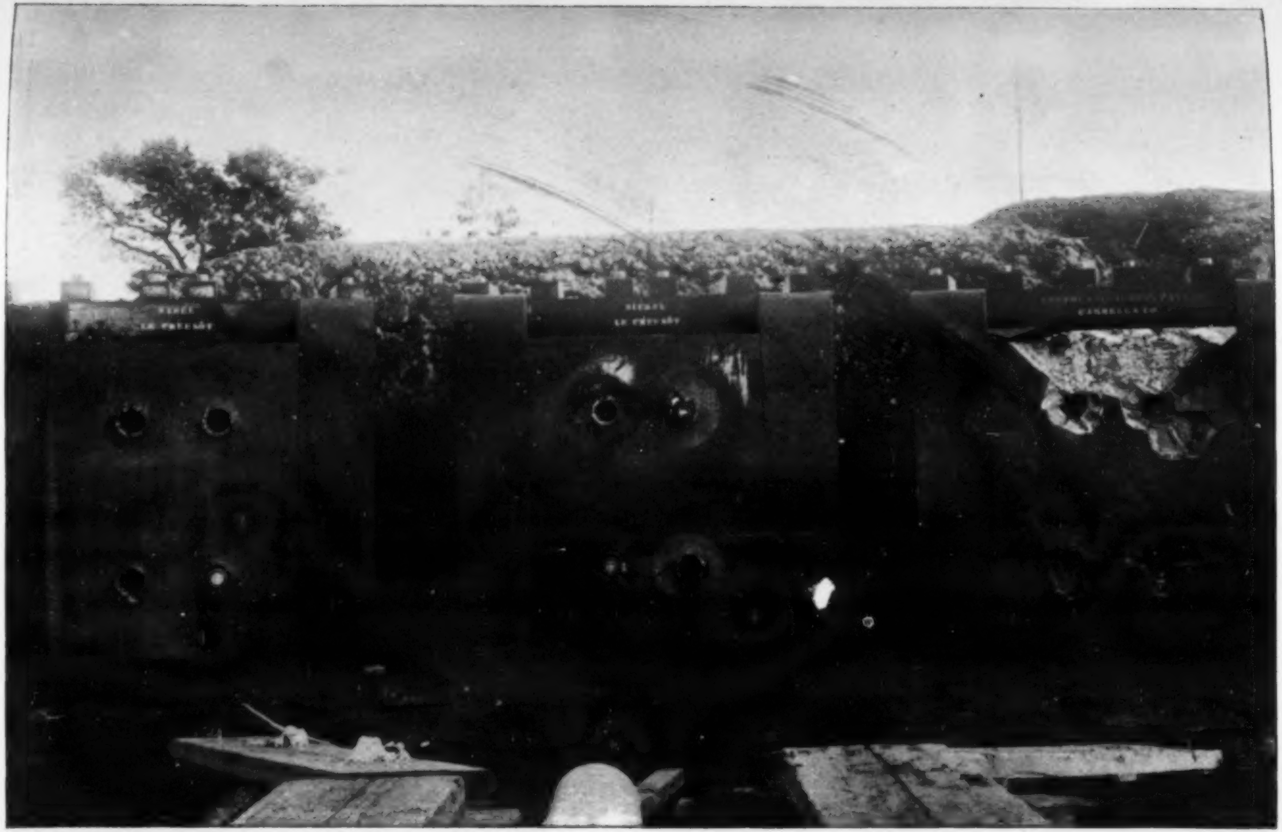
No. 16. COMPOUND PLATE AFTER FOURTH SHOT.

Fragments of Steel Face Collected in Front of Plate.



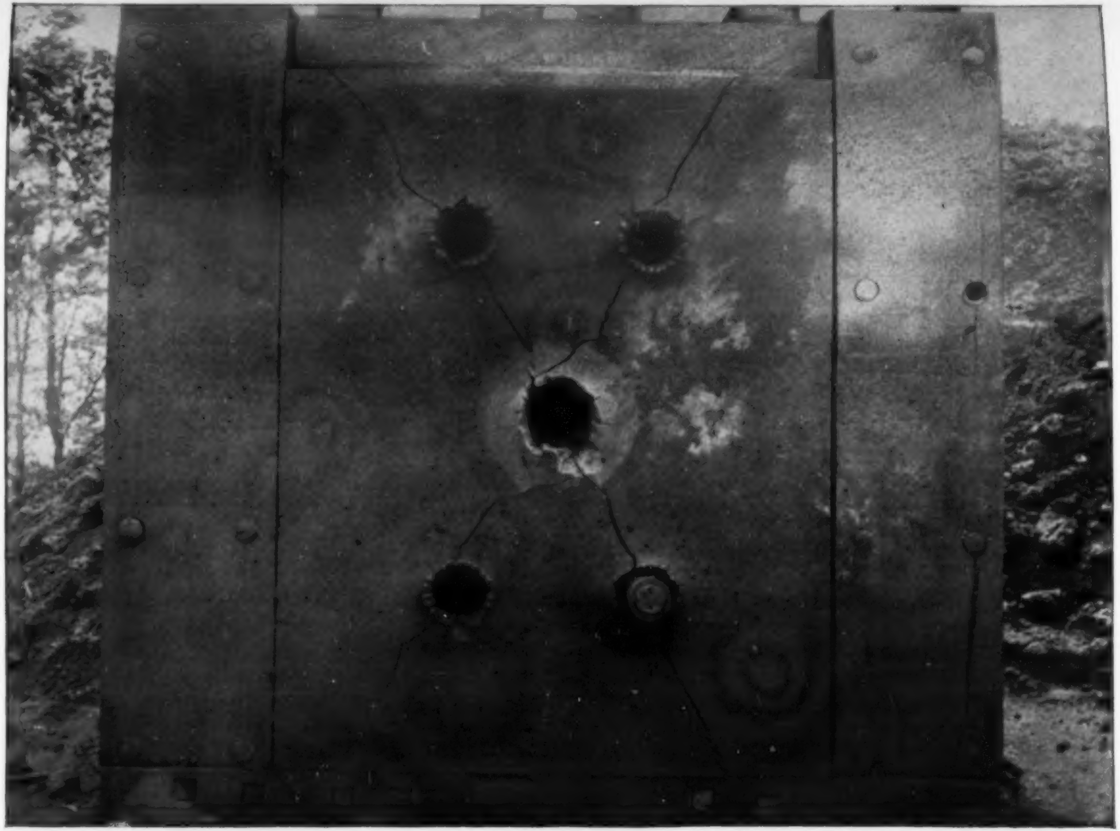
No. 17. RECOVERED SIX-INCH PROJECTILES.

FIGURES REFER TO SERIAL NUMBER OF ROUNDS.



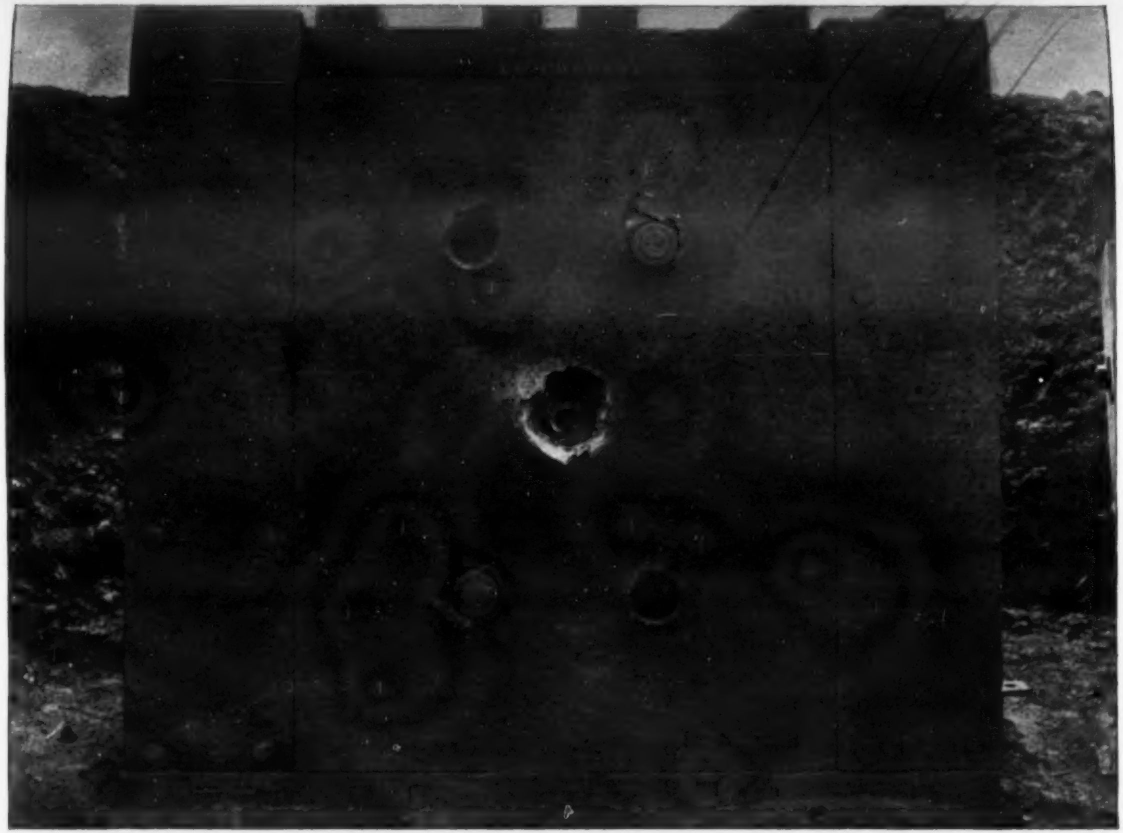
Schneider et Cie. Schneider et Cie. Cammell & Co.

No. 18. VIEW OF PLATES AFTER FOUR SHOTS EACH.



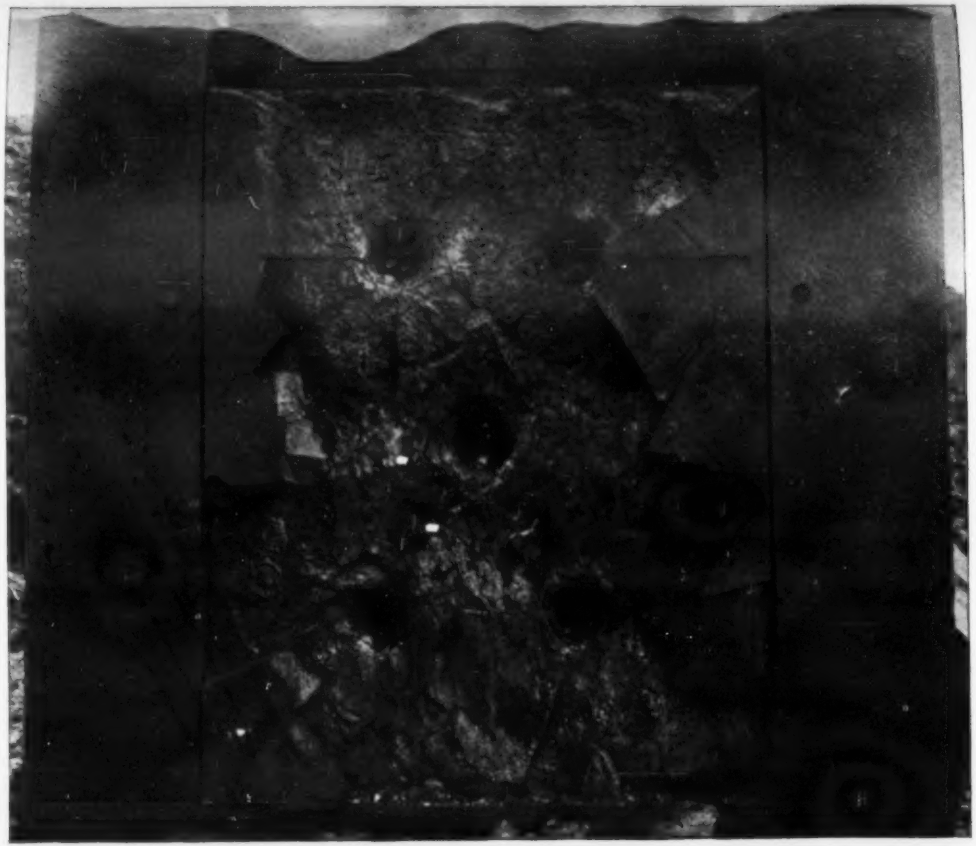
No. 19. STEEL PLATE AFTER FIFTH SHOT.

(Schneider et Cie.)



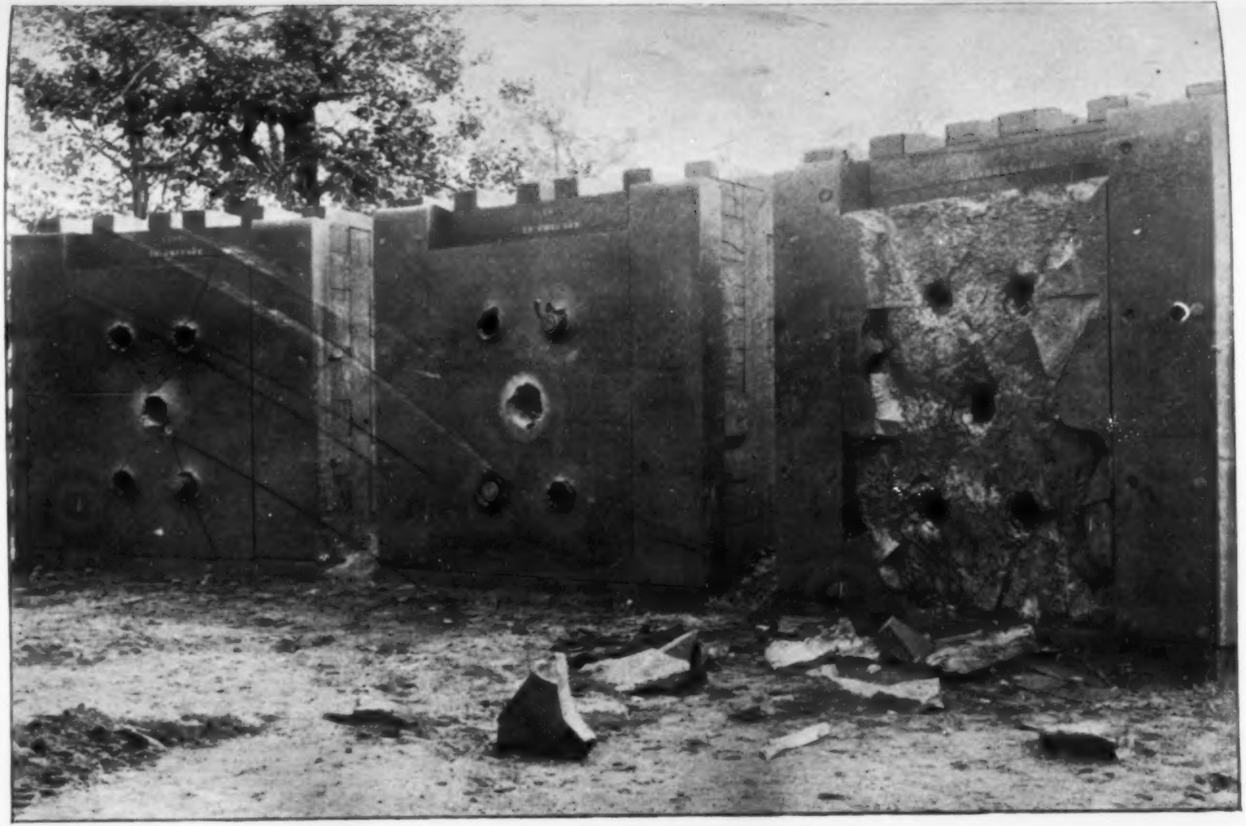
No. 20. NICKEL-STEEL PLATE AFTER FIFTH SHOT.

(Schneider et Cie.)



No. 21. COMPOUND PLATE AFTER FIFTH SHOT.

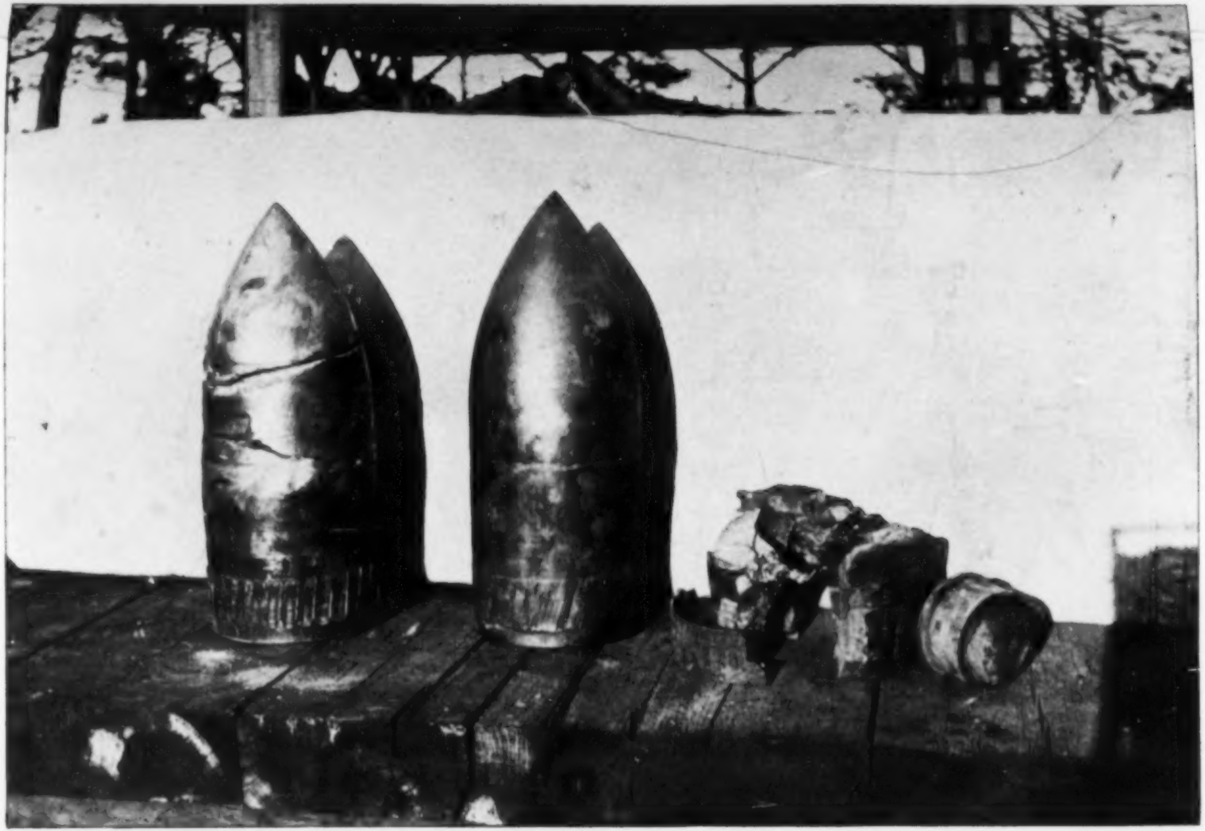
(Cammell & Co.)



Schneider et Cie. Schneider et Cie. Cammell & Co.

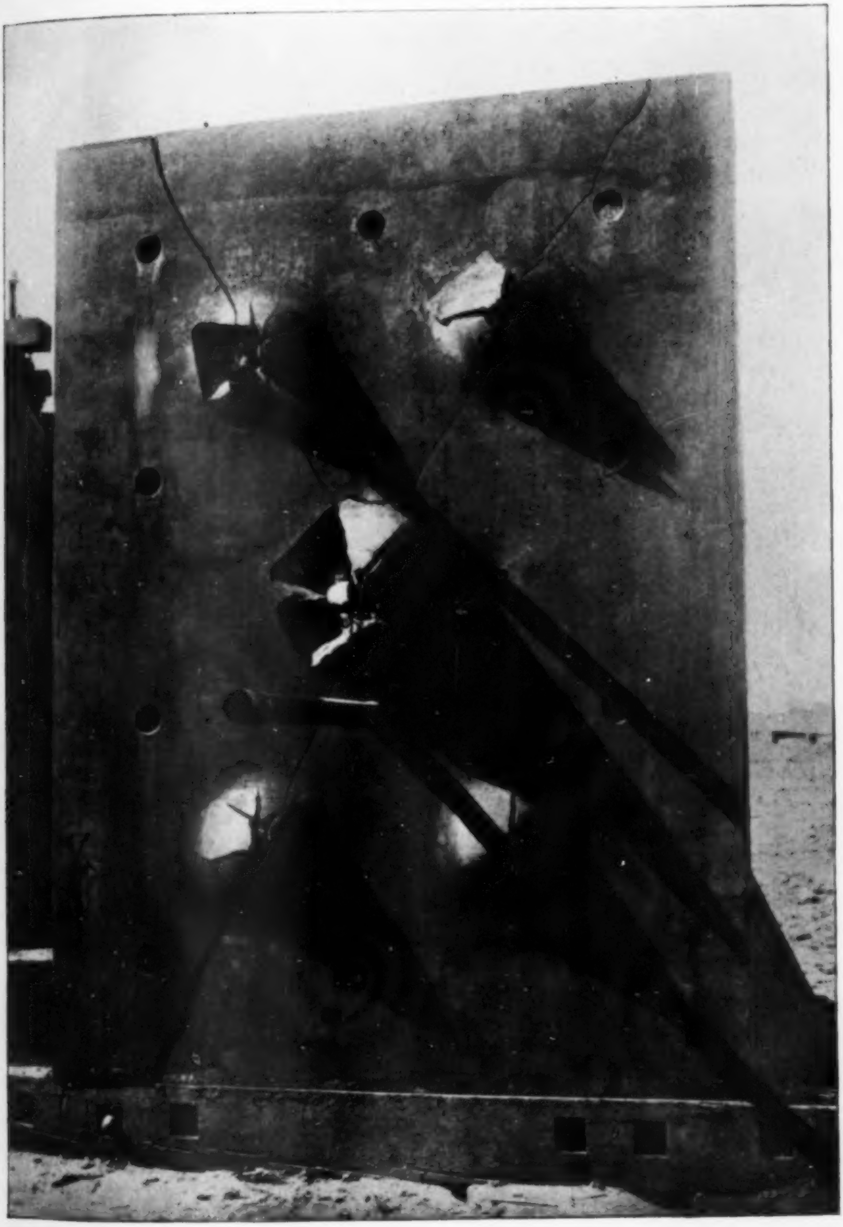
No. 22. VIEW OF PLATES AFTER FIVE SHOTS EACH.

Fragments of Compound Plate in Position in which They Fell.



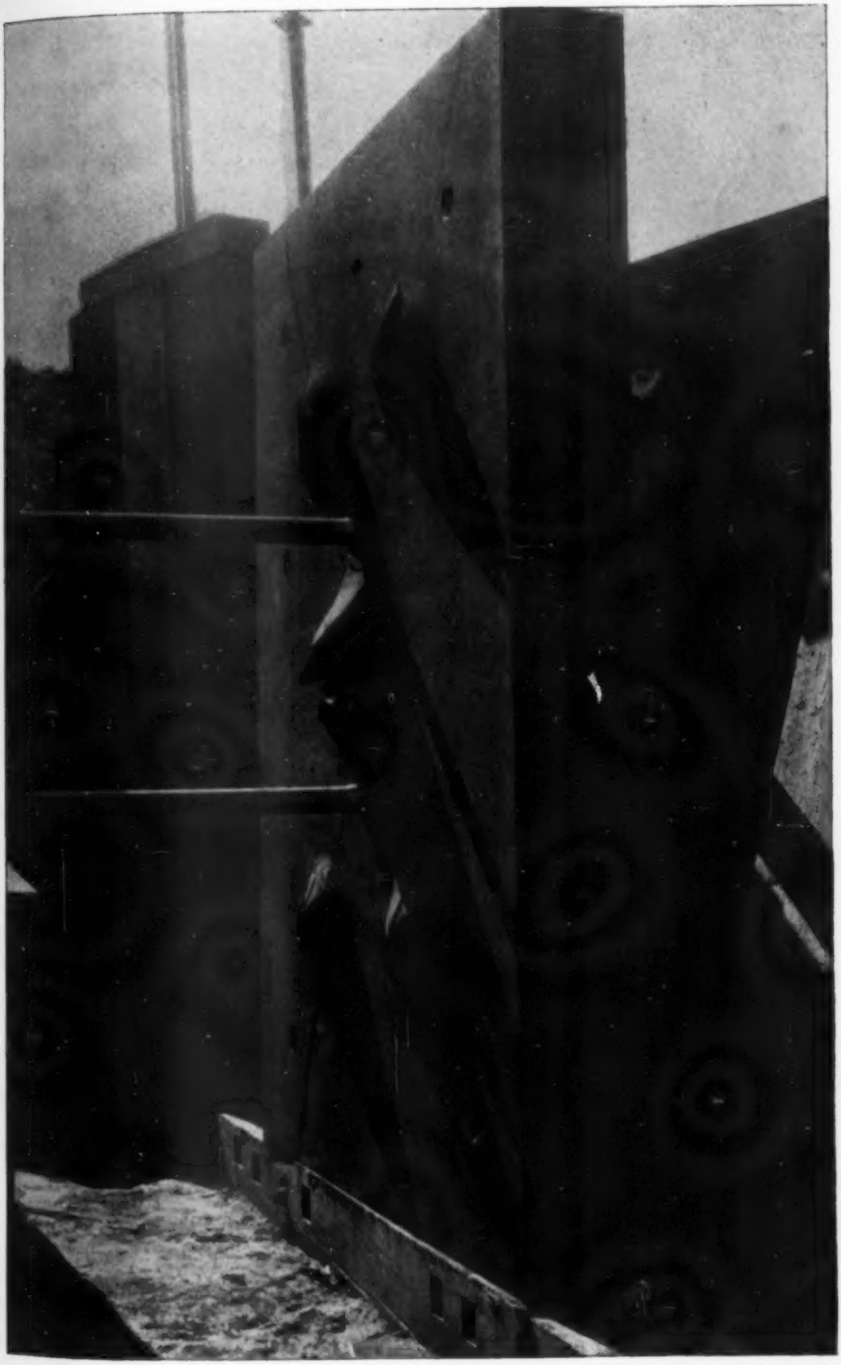
Fired at Steel Plate. Fired at Compound Plate. Fired at Nickel-Steel Plate.

No. 23. RECOVERED EIGHT-INCH PROJECTILES.



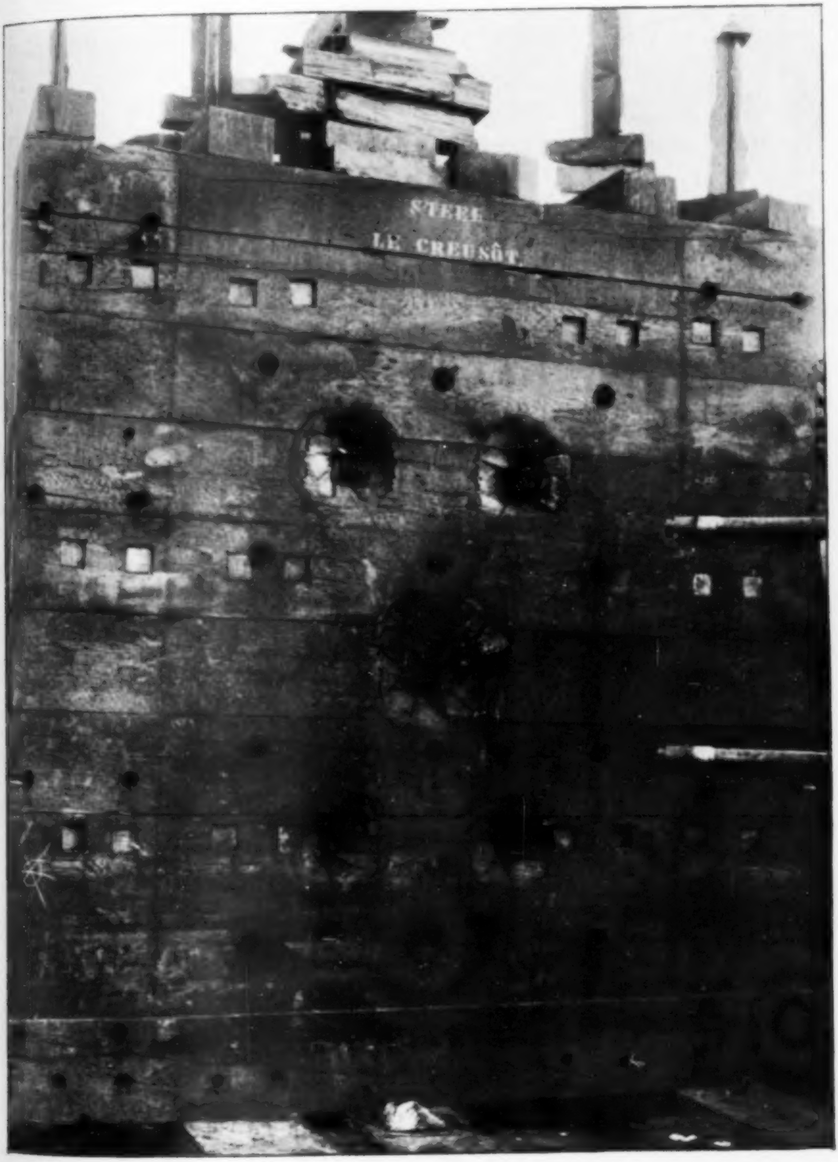
No. 24. BACK OF STEEL PLATE.

(Schneider et Cie.)

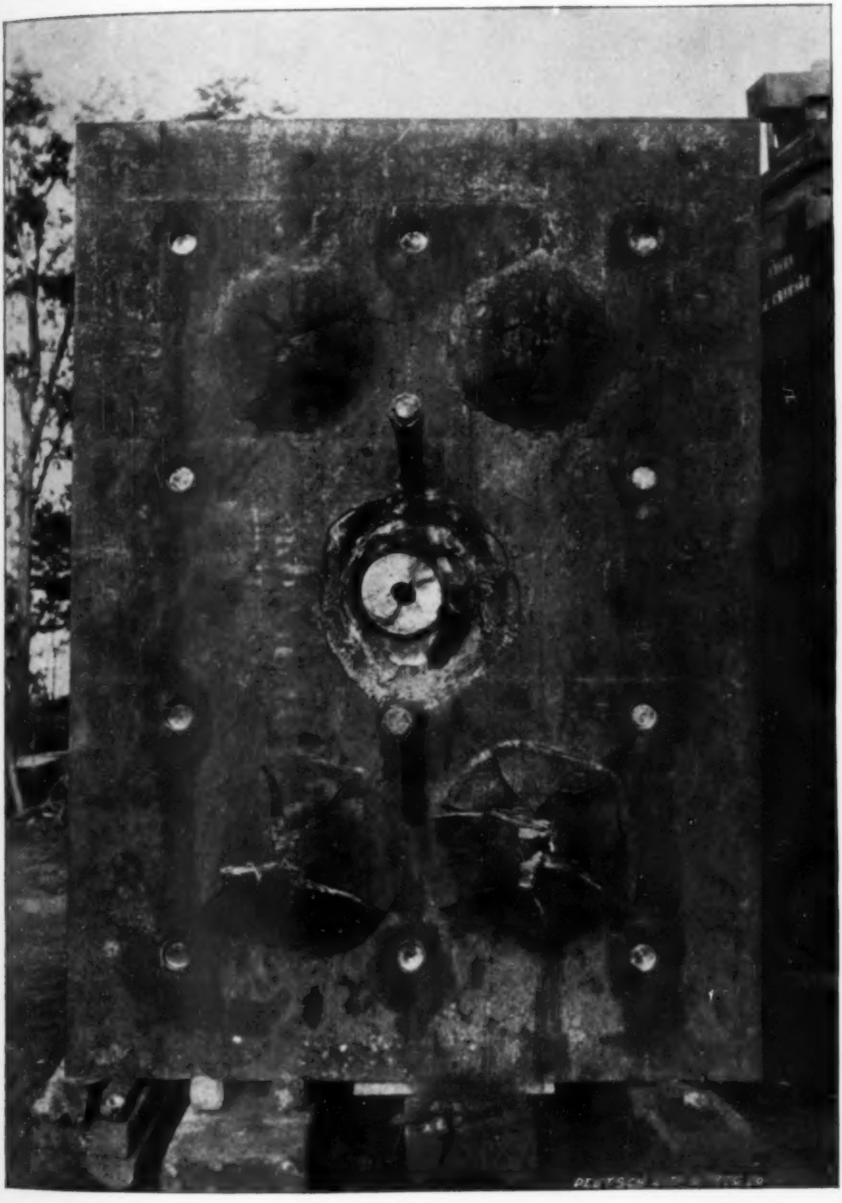


No. 24a. BACK OF STEEL PLATE.

(Schneider et Cie.)

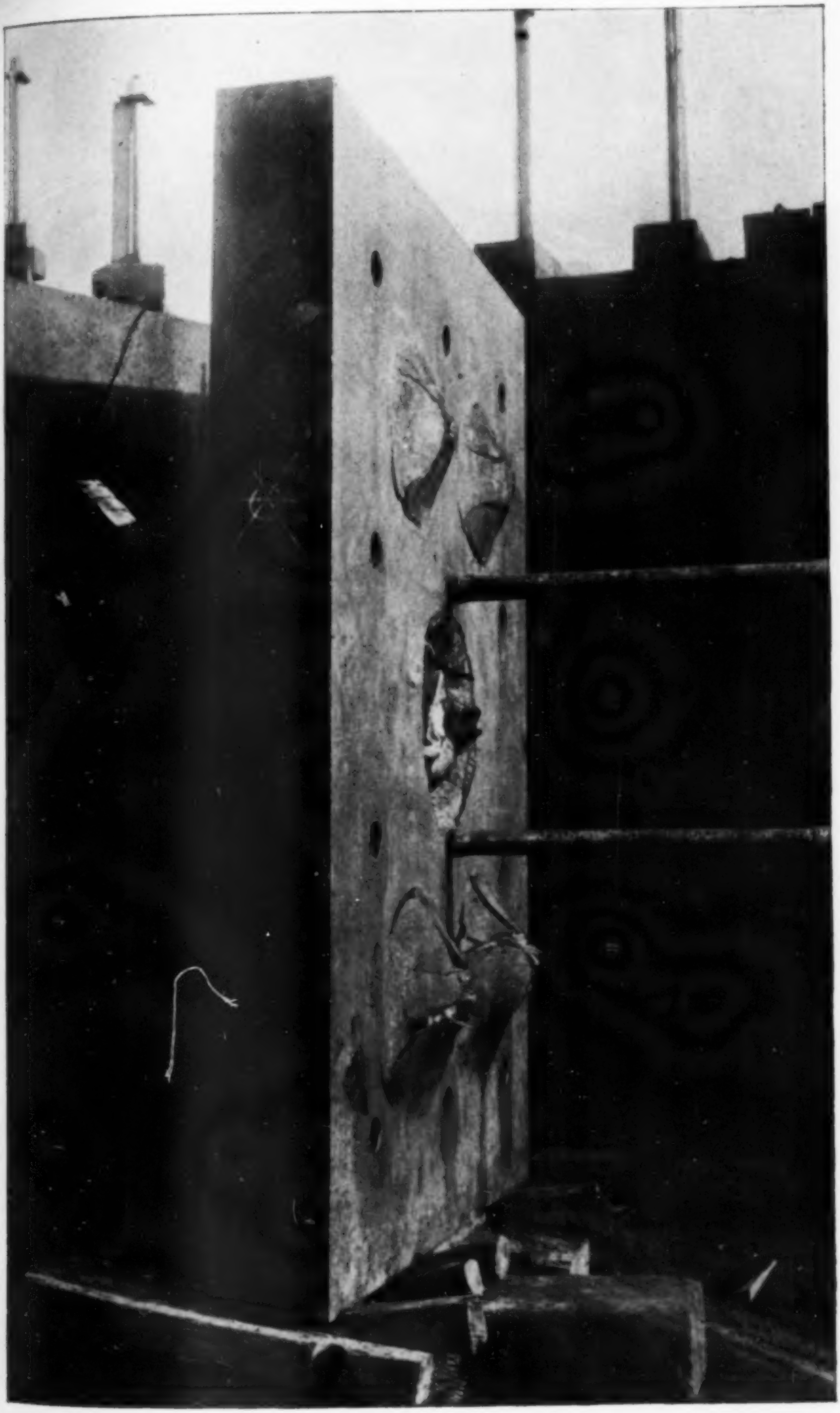

STEEL
LE CREUSOT

No. 25. BACKING OF STEEL PLATE.



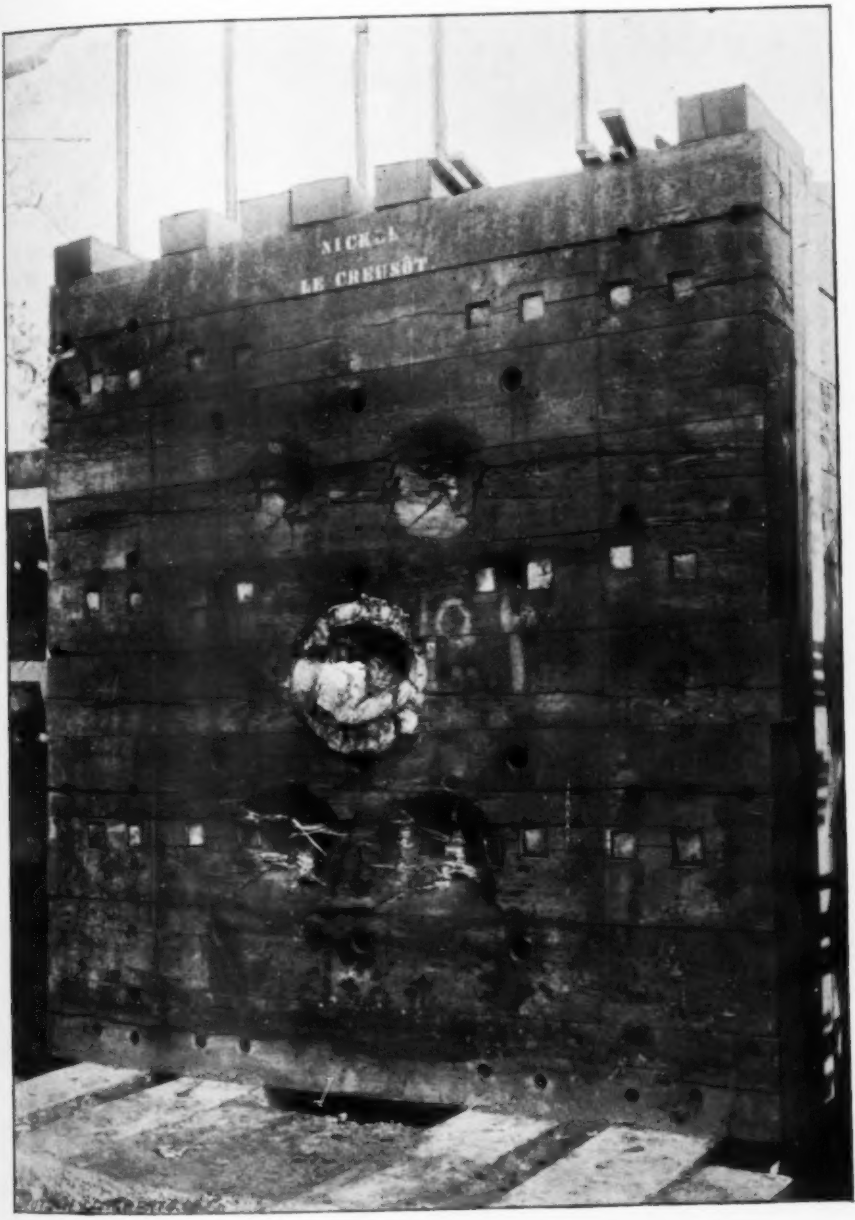
No. 26. BACK OF NICKEL-STEEL PLATE.

(Schneider et Cie.)

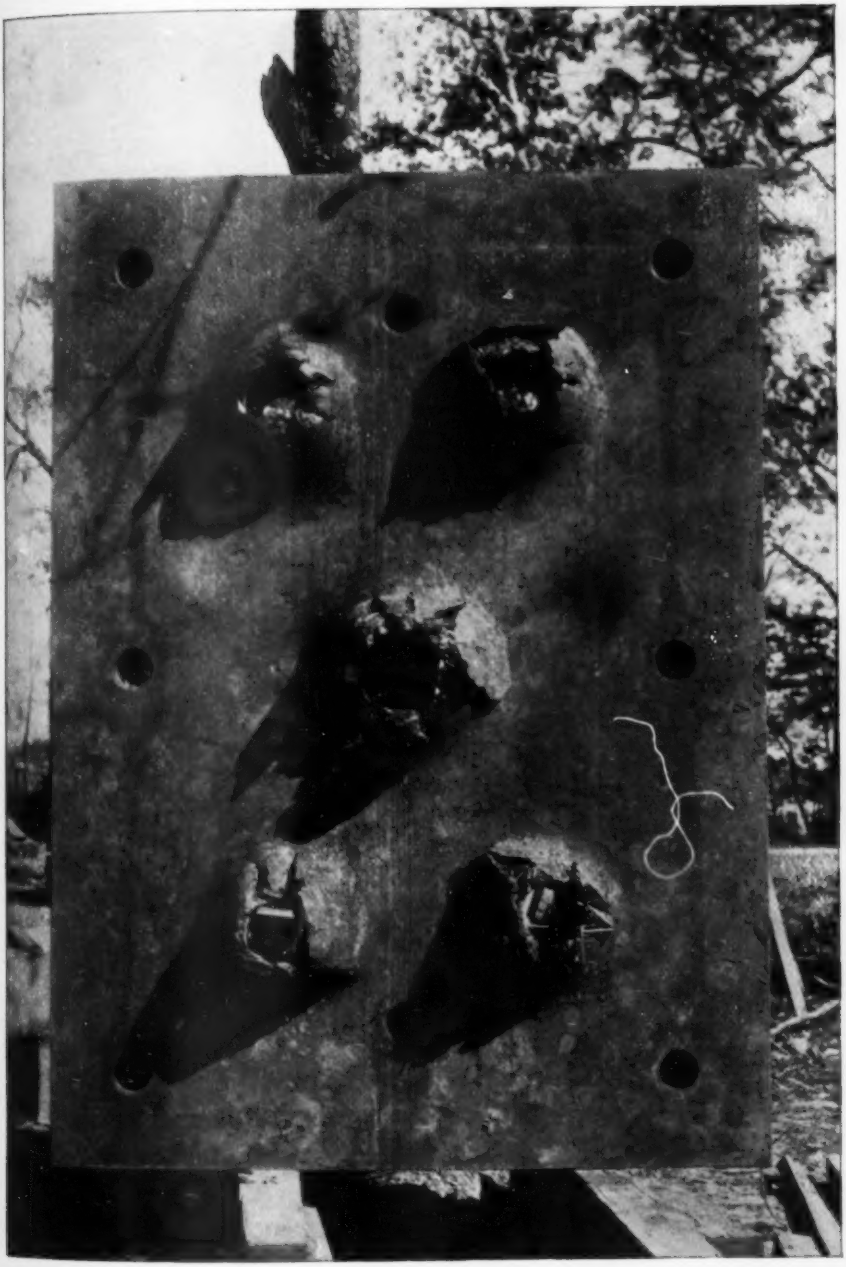


No. 26a. BACK OF NICKEL-STEEL PLATE.

(SCHNEIDER ET CIE.)

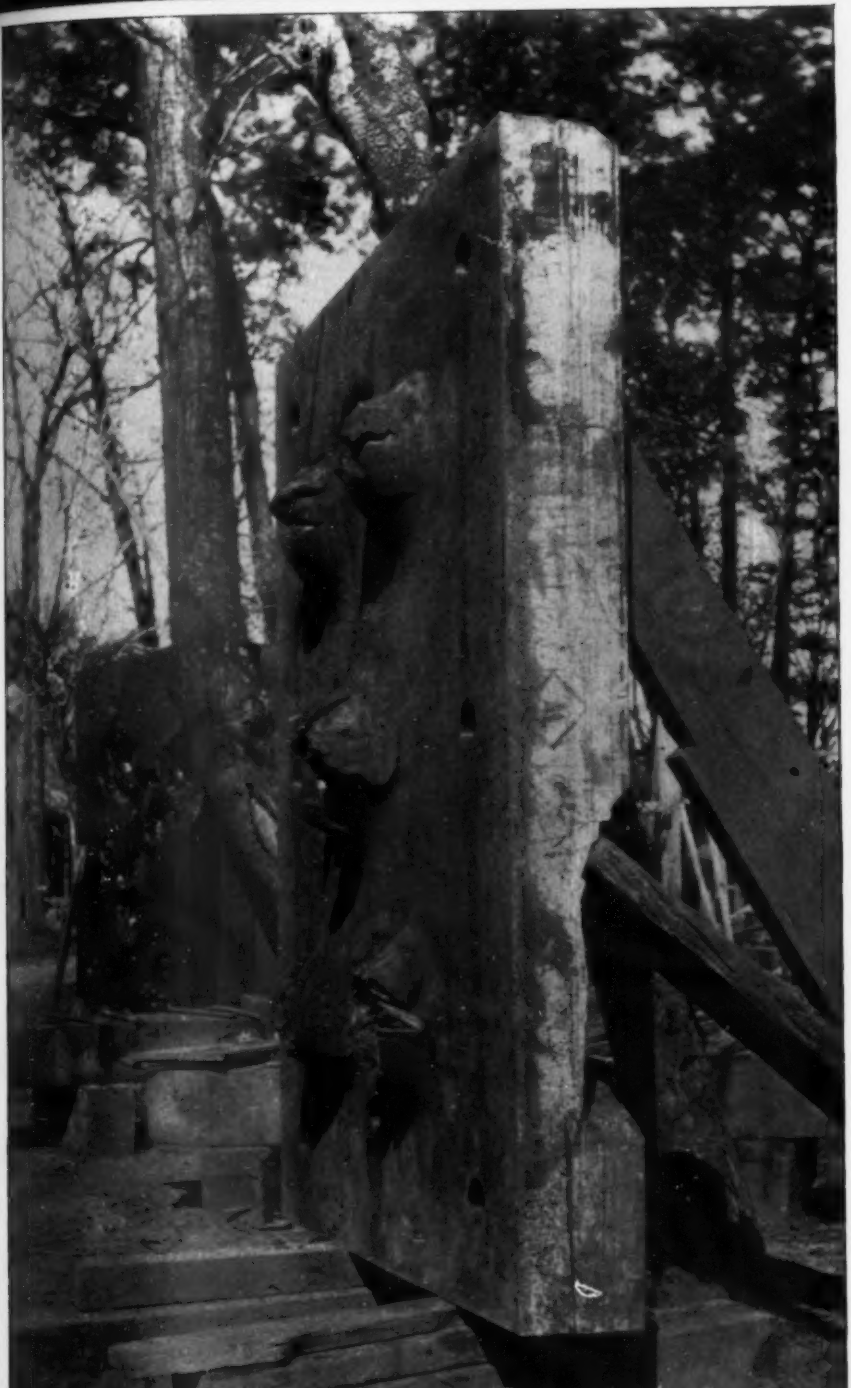

NICKEL
LE CREUSOT

No. 27. BACKING OF NICKEL-STEEL PLATE.



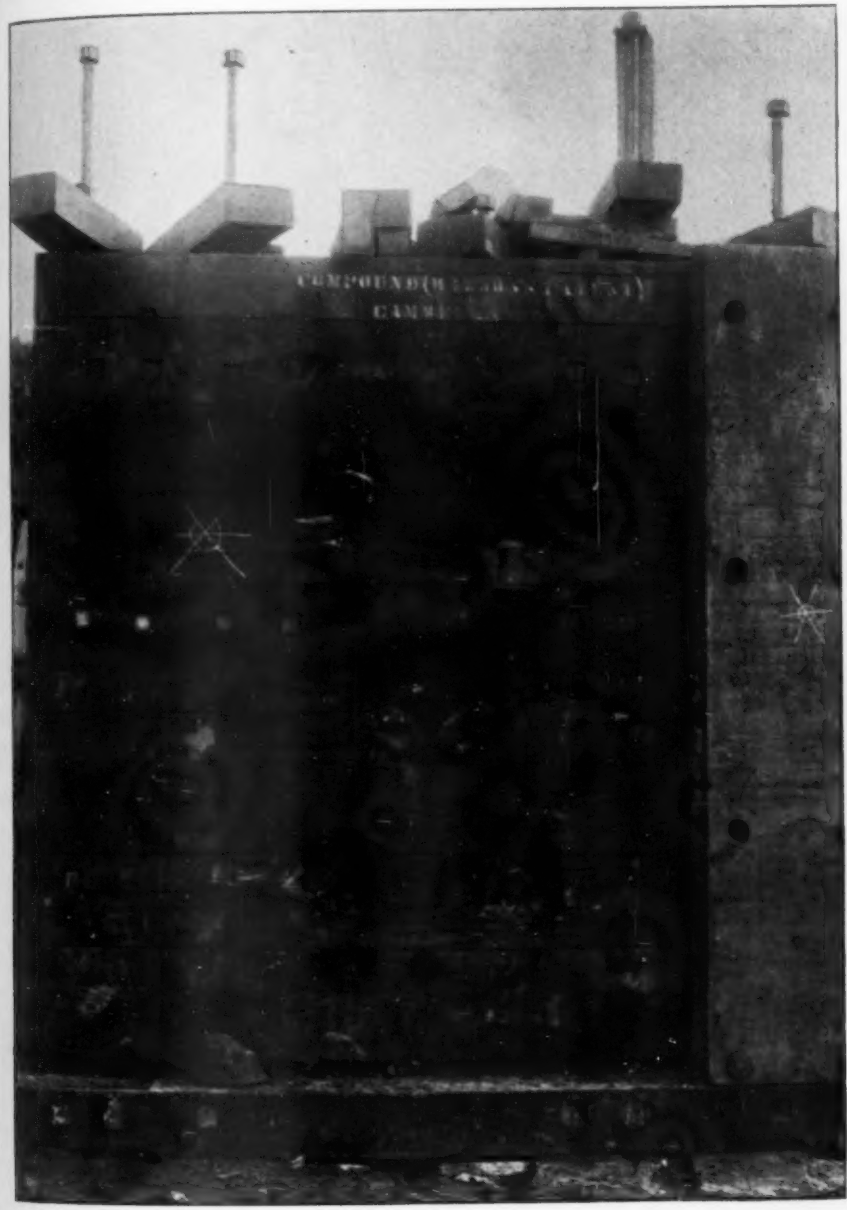
No. 28. BACK OF COMPOUND PLATE.

(Cammell & Co.)



No. 28a. BACK OF COMPOUND PLATE.

(Cammell & Co.)



No. 29. BACKING OF COMPOUND PLATE.

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Dr. Edward G. Love, formerly analytical chemist for the U. S. Government, who made the analyses for the New York State Board of Health in their investigation of baking powders, says of the purity and wholesomeness of the "Royal":

"I find the Royal Baking Powder composed of pure and wholesome ingredients. It is a cream of tartar powder, and does not contain either alum or phosphates, or other injurious substance.

(Late U. S. Gov't Chemist) "E. G. LOVE, PH. D."

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NOTICE.

The U. S. Naval Institute was established in 1873, having for its object the advancement of professional and scientific knowledge in the Navy. It now enters upon its eighteenth year of existence, trusting as heretofore for its support to the officers and friends of the Navy. The members of the Board of Control cordially invite the coöperation and aid of their brother officers and of others interested in the Navy, in furtherance of the aims of the Institute, by the contribution of papers and communications upon subjects of interest to the naval profession, as well as by personal support and influence.

On the subject of membership the Constitution reads as follows:

ARTICLE VII.

SEC. 1. The Institute shall consist of regular, life, honorary, and associate members.

SEC. 2. Officers of the Navy, Marine Corps, and all civil officers attached to the Naval Service, shall be entitled to become regular or life members, without ballot, on payment of dues or fee to the Secretary and Treasurer, or to the Corresponding Secretary of a Branch. Members who resign from the Navy subsequent to joining the Institute will be regarded as belonging to the class described in this Section.

SEC. 3. The Prize Essayist of each year shall be a life member without payment of fee.

SEC. 4. Honorary members shall be selected from distinguished Naval and Military Officers, and from eminent men of learning in civil life. The Secretary of the Navy shall be, *ex-officio*, an honorary member. Their number shall not exceed thirty (30). Nominations for honorary members must be favorably reported by the Board of Control, and a vote equal to one-half the number of regular and life members, given by proxy or presence, shall be cast, a majority electing.

SEC. 5. Associate members shall be elected from officers of the Army, Revenue Marine, foreign officers of the Naval and Military professions, and from persons in civil life who may be interested in the purposes of the Institute.

SEC. 6. Those entitled to become associate members may be elected life members, provided that the number not officially connected with the Navy and Marine Corps shall not at any time exceed one hundred (100).

SEC. 7. Associate members and life members, other than those entitled to regular membership, shall be elected as follows: Nominations shall be made in writing to the Secretary and Treasurer, with the name of the member making them, and such nominations shall be submitted to the Board of Control, and, if their report be favorable, the Secretary and Treasurer shall make known the result at the next meeting of the Institute, and a vote shall then be taken, a majority of votes cast by members present electing.

The Proceedings are published quarterly, and may be obtained by non-members upon application to the Secretary and Treasurer at Annapolis, Md. Inventors of articles connected with the naval profession will be afforded an opportunity of exhibiting and explaining their inventions. A description of such inventions as may be deemed, by the Board of Control, of use to the service, will be published in the Proceedings.

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